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Contents:

MODERN MANUFACTURING METHODS FOR THE PRODUCTION OF STEEL SHEETS
by H. H. STANLEY, A.Met.

THE APPLICATION OF TUNGSTEN CARBIDE CUTTING TOOLS
by C. EATOUGH, B.Sc.(Tech.,) M.I.Mech.E., and H. ECKERSLEY, M.I.P.E., M.I.Mech.E.

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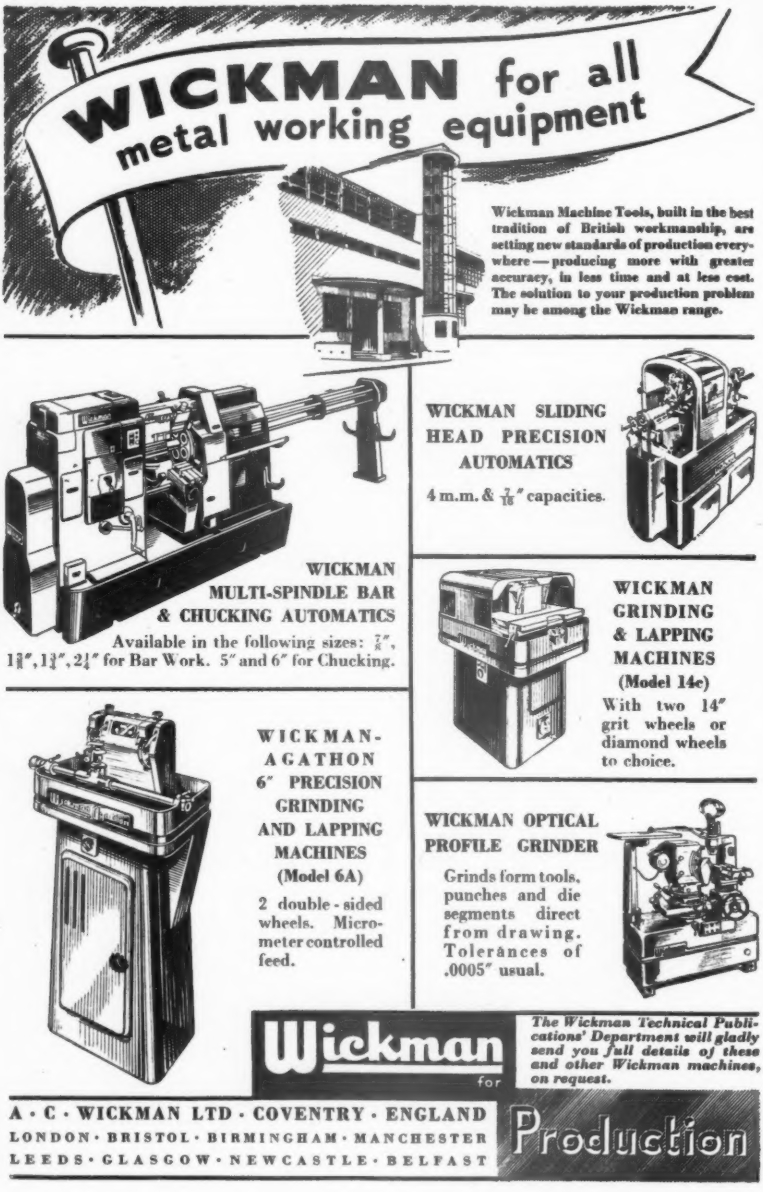
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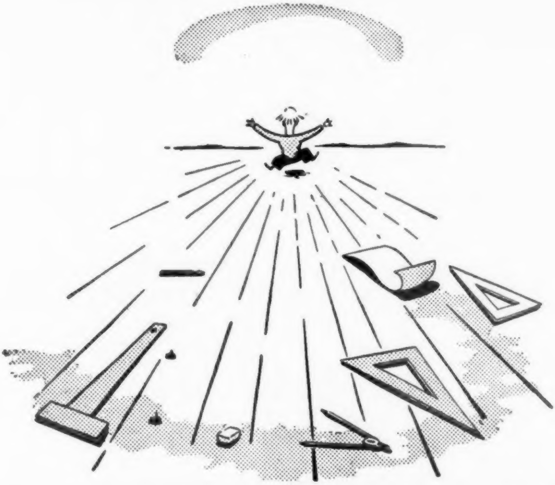

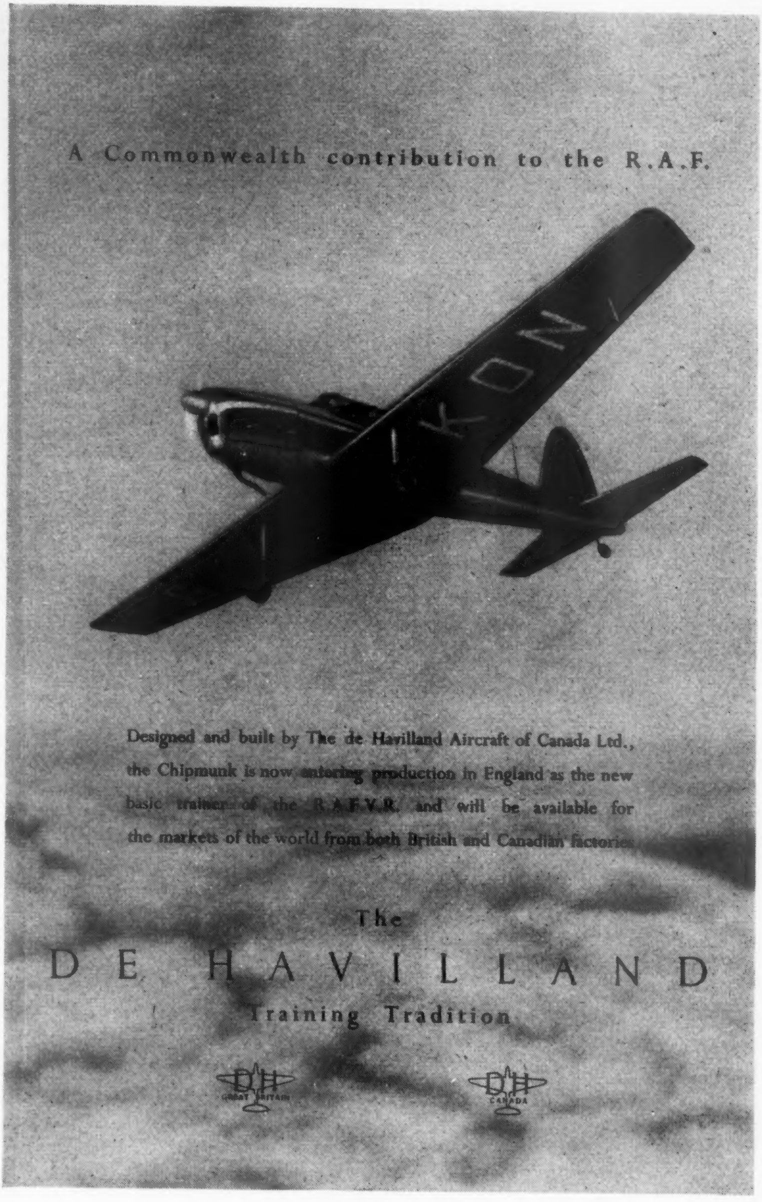
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A MESSAGE FROM THE PRESIDENT

Dr. Herbert Schofield, C.B.E., B.Sc.(Lond)., A.R.C.Sc.(Lond)., D.I.C., M.I.P.E., M.I.Struct.E., A.M.I.C.E., A.M.I.E.E., F.Inst.P., F I.I.A.

I have very much pleasure in informing you that the proposal to increase the subscriptions at the Extraordinary General Meeting held on April 28th, 1949, was carried by a unanimous vote. This may be taken as a vote of confidence in the way in which your Council are conducting the affairs of the Institution.

You may remember that three years ago the Chancellor of the Exchequer called upon all sections of the community to avoid introducing any measures which might tend to create inflationary pressure. Although your Council realised at that time that the level of membership subscriptions was not adequate to meet the demand occasioned by the general post-war increase in prices, nevertheless in the interest of our national recovery the necessary action was deferred. The result of this patriotic gesture has been that the Institution has incurred a deficit in the accounts for the past year.

All other leading professional institutions have been faced with the same dilemma, and over the past year or two they have all found it necessary to increase their membership subscriptions.

In deciding upon the new rates, your Council were aware that they might meet some criticism, but they have decided—and I am sure you will agree that this was a very wise decision—that the new rates of subscription should not only settle our immediate financial problems, but should also provide a margin for the future growth of the Institution. For example, the lease of the present Headquarters, at 36, Portman Square expires in 1960, and this may involve the Institution in considerable expenditure in finding new premises. For this reason alone, it is essential that adequate funds are accumulated.

Government departments and responsible public bodies are looking to our Institution more and more for advice and guidance on productivity problems, and it is your Council's policy to establish the Institution of Production Engineers as the leading national body on productivity in every branch of industry. With the

changing social conditions brought about by present day economic trends, professional institutions—because of the high standard of professional skill on the part of their members—will be increasingly called upon for advice and guidance by the Government of the day, whatever political party they may represent. The policy of your Council, if vigorously pursued, must considerably enhance the status and reputation of the Institution and thereby increase the status of each individual member. I am sure you will agree with me, therefore, that it is essential for the Institution to adopt every possible measure to increase its strength and widen its activities, in order to be in a position to satisfy any public demand which it may be called upon to meet.

A close study of modern industrial trends leads me to the inevitable conclusion that the Institution of Production Engineers is destined to become, in its own sphere, one of the most important bodies in the kingdom, and I therefore appeal to each member not only to have faith in the future and continue to give the Institution the utmost support, but also to do everything he can to bring to its ranks men of the highest calibre in industry.

(Photograph of Dr. Schofield by courtesy of "Scope.")

INSTITUTION NOTES

August, 1949

BIRMINGHAM GRADUATE CONVENTION A Convention on "Training and Leadership in Industry" is being held by the Birmingham Graduate Section at Birmingham University on Saturday, September 3rd, 1949. Invitations have been extended to all Graduates and Students of the Institution, and it is anticipated that representatives from all sections will attend.

The Conference President will be Professor T. U. Matthew, Ph.D., M.Sc., A.R.T.C., Wh.Sch., M.I.P.E., A.M.I.Mech.E., M.I.Chem.E., M.S.A.I.E.

PROGRAMME

9.15 a.m.	Conference Assembles.
9.30 a.m.	Opening Address by Professor T. U. Matthew.
9.45 a.m.	Address by T. B. Worth, Esq., M.I.P.E., M.I.Mech.E., A.M.I.E.E., The Institution's Education Officer, on "Qualification and Further Education."
10.30 a.m.	Address by K. R. Evans, Esq., M.A., A.M.I. Mech.E., A.M.I.E.E., M.I.P.M., Manager of the Education Department of Metropolitan Vickers Electrical Co. Ltd., on "Industry's Part in a Balanced Training."
11.15 a.m.	Discussion on first two addresses.
12.30 p.m.	Luncheon.
1.30 p.m. to 2.50 p.m.	Tour of the Electron Physics, Electrical Engineering and Production Engineering Departments of the University.
3.0 p.m.	Address by Major General K. C. Appleyard, C.B.E., D.L., T.D., J.P., M.I.P.E., M.I.Mech.E., M.I.Min.E., A.I.Mar.E., The President-Elect of the Institution, on "Youth and Leadership in Industry."
3.45 p.m.	Discussion.
4.15 p.m.	Tea.
4.45 p.m.	Closing Address by Professor T. U. Matthew.
5.30 p.m.	Convention Ends.

The Conference fee is 10s. 6d., and those wishing to attend should communicate with R. V. Brown, Esq., Grad.I.P.E., Chairman of the Birmingham Graduate Section, at 37, Cranfield Grove, Yardley, Birmingham.

HONOURS The Institution is pleased to record that the names of two members appeared in the recent Birthday Honours List.

They were Mr. J. A. T. Dickinson, M.I.P.E., Director and General Works Manager of the Birmingham Small Arms Co. Ltd., Birmingham, and Mr. H. Turner, M.I.P.E., M.I.Mech.E., Deputy Superintendent of the Royal Naval Torpedo Factory, Greenock, who both received the O.B.E.

TECHNICAL EDUCATION Applications are invited for the appointment of Lecturer in Engineering subjects for National Certificate, City and Guilds, and Junior Technical courses, at the Walker Technical College, Hartshill, Oakengates, Shropshire. A bias towards Machine Shop Engineering is desirable but not essential.

Candidates should have had good industrial experience and should hold a recognised qualification of at least the standard of Higher National Certificate (in Production Engineering preferably) or its equivalent. Applications should give age, qualifications, industrial and teaching experience, and other relevant particulars with dates, which should be sent with copies of two testimonials and the names and addresses of two referees to reach the Principal as soon as possible.

NEWS OF MEMBERS

Mr. R. A. Anson, Grad.I.P.E., A.M.I.Mech.E., is now Assistant Chief Engineer with H. J. Enthoven and Sons, Ltd., London.

Mr. A. E. Bell, M.I.P.E., has been appointed Head of the Department of Engineering, County Technical College, Wednesbury.

Mr. L. E. Craddock, Grad.I.P.E., is now Assistant Technical Officer with I.C.I. Ltd., (Metals Division), Witton.

Mr. T. W. Fazakerley, M.I.P.E., F.I.I.A., A.R.Ae.S., F.R.Econ.S., F.F.S., recently resigned his position of General Manager and Director of the P.B.Cow Group of Companies.

Mr. S. G. Lane, Int.A.M.I.P.E., has been appointed Specialist Demonstrator for the Argon Arc Welding Process in the South Eastern Home Counties and Eastern Counties districts.

Mr. F. P. Laurens, O.B.E., M.I.P.E., M.I.Mech.E., has been appointed to the Board of Vickers-Armstrongs, Ltd., and will shortly take up his duties as Director-in-charge of Engineering at the Vickers-Armstrongs Works at Barrow-in-Furness.

Mr. B. G. Mann, A.M.I.P.E., A.M.I.Mech.E., is now Technical Director of The Marine Engineering Co. (Stockport) Ltd., Stockport.

Mr. W. D. Opher, M.I.P.E., M.I.Mech.E., Works Superintendent at Vickers-Armstrongs, Ltd., Crayford, has been appointed a Special Director of the Company.

Mr. Edward Overend, A.I.P.E., is now Principal of Stretford Technical College, near Manchester.

Mr. R. A. Powley, A.M.I.P.E., A.M.I.W., M.A.W.S., Mem.A.S.T.E., is now Engineer-in-charge of the Experimental Department of the I.T.E. Circuit Breaker Co., Philadelphia, Pa. (Special Products Division).

Mr. H. G. Rust. A.I.P.E., A.M.I.Mech.E., is now Technical Assistant in the Chief Engineer's Department, Mechanical Division, London County Council.

Mr. C. H. Samson, A.M.I.P.E., is now Assistant Manager of the Royal Ordnance Factory, Maltby, near Rotherham, Yorkshire.

Mr. E. W. H. Scaife, Grad.I.P.E., has been appointed Technical Representative with Machine Tools (India) Ltd., and Machine Tools (Pakistan) Ltd. He will be leaving for India in the autumn.

Mr. W. A. Smyth, M.I.P.E., is now General Manager of Henry Meadows, Ltd., Fallings Park Engine Works, Wolverhampton.

Mr. C. J. Uridge, Grad.I.P.E., has been appointed Gas Engineer at Moffats, Ltd., Weston, Ontario.

Mr. A. Vernon Watson, A.M.I.P.E., A.I.Mech.E., has been elected President of the Institution of Engineering Inspection.

Mr. G. A. Wood, A.M.I.P.E., A.M.I.Mech.E., formerly of Associated Industrial Consultants, Ltd., is shortly taking up an appointment as Lecturer in Production Engineering at the Sydney Technical College, New South Wales.

BOOKS RECEIVED

"Mathematics at Work" by Holbrook L. Horton. Industrial Press of New York (British Empire distributors: Machinery Publishing Co. Ltd., Brighton). 37/6d. net.

"Mathematics at Work" is a handbook of worked examples encountered in practice, and is in some measure a companion volume to "Machinery" Handbook. The problems have been chosen from a number submitted to the editors for solution and the selection has been made to enable other problems to be solved by analysis and application of formulae.

The book also contains tables of mathematical data and a digest of certain important elements in arithmetic, algebra, geometry and trigonometry, though it makes no claim to give an exhaustive treatment to any of these.

Problems in technical measurement, gearing and clutches, templates and some design and mechanics illustrate the nature of the book and a useful chapter on trial and error solutions will encourage logical approach to problems. The practical approach used makes the book suitable for draughtsmen, inspectors, toolmakers, and others in close association with shop problems, but it also affords examples of applied theory of interest to students.

T.B.W.

" Electronics in the Factory " by Professor H. F. Trewman, M.A.(Cantab.), M.I.E.E., M.I.Mech.E., M.Brit.I.R.E. Sir Isaac Pitman, London. 20/- net.

" The Modern Diesel," edited by G. Geoffrey Smith, M.B.E., revised and rewritten by Donald H. Smith, M.I.Mech.E., Assoc.Inst.T. Iliffe & Sons. Ltd. 7/6d. net.

ISSUE OF JOURNAL TO NEW MEMBERS Owing to the fact that output has to be adjusted to meet requirements, and in order to avoid carrying heavy stocks, it has been decided that the Journal will only be issued to new Members from the date they join the Institution.

IMPORTANT In order that the Journal may be despatched on time, it is essential that copy should reach the Head Office of the Institution not later than 40 days prior to the date of issue, which is the first of each month.

"Fabrication as Applied to Light and Medium Sized Components"

by R. M. Watts.

The author of the above paper, which was published in the June issue of the Journal, has informed us that the table published on page 312 is incorrect and was submitted in error.

The corrected table is therefore reprinted below.

Combination of metals which may be resistance welded.

Metals.	Aluminium	Stainless Steel	Brass	Copper	Galvd. Iron	Steel	Lead	Monel	Nickel	Nichrome	Tin plate	Zinc	Phos. Bronze	Nickel Silver	Terneplate
Aluminum	×										×	×			
Stainless Stl. ...		×	×	×	×	×		×	×	×	×		×	×	×
Brass		×	×	×	×	×		×	×	×	×	×	×	×	×
Copper		×	×	×	×	×		×	×	×	×	×	×	×	×
Galvanized Iron ...		×	×	×	×	×	×	×	×	×	×		×	×	×
Steel		×	×	×	×	×		×	×	×	×		×	×	×
Lead					×		×				×	×		×	×
Monel		×	×	×	×	×		×	×	×	×		×	×	×
Nickel		×	×	×	×	×		×	×	×	×		×	×	×
Nichrome		×	×	×	×	×		×	×	×	×		×	×	×
Tin Plate	×	×	×	×	×	×	×	×	×	×	×		×	×	×
Zinc	×		×	×			×					×			
Phos. Bronze ...		×	×	×	×	×		×	×	×	×		×	×	×
Nickel Silver ...		×	×	×	×	×	×	×	×	×	×		×	×	×
Terneplate		×	×	×	×	×	×	×	×	×	×		×	×	×

MODERN MANUFACTURING METHODS FOR THE PRODUCTION OF STEEL SHEETS

By H. H. STANLEY, A.Met.

Presented to the West Wales Sub-Section of the Institution, February 4th, 1949.

Steel sheets belong to the class of iron and steel products known as flat rolled products ; all members of this class are produced by rolling in a mill provided with flat rolls, and in all cases the width is considerably greater than the thickness. In the case of sheets, the ratio of width to thickness is several hundred to one, and in the case of some of the very thin sheets used by the electrical industry this ratio may be two or three thousand to one. Flat rolled products include plate, sheet, tinplate, bar, strip, and band. The sub-division into these groups is mainly because of the type of mill required to produce the various combinations of width and thickness. Thus, a mill which is satisfactory for producing material 6 ft. wide and $\frac{3}{4}$ in. thick, is totally unsuitable for producing material 3 ft. wide and 0.014 in. thick.

The bulk of the sheets produced lie within the thickness range of 0.1 in. to 0.01 in., although sheet mills sometimes produce material thicker than $\frac{1}{8}$ in. and so overlap with the light plate mills.

The width of sheets normally lies between 2 ft. and 6 ft. as rolled, and the length between 3 ft. and 15 ft. In this country strip originally referred to material under 18 in. wide and generally under $\frac{1}{8}$ in. thickness, and it was produced in long lengths and was often coiled straight from the mill. During the last 10 or 20 years, however, wide strip mills have been developed which are able to produce material up to 8 ft. in width. These mills, together with their ancillary equipment, are capable of producing what was originally rolled by the light plate mills, sheet mills, tinplate mills and narrow strip mills. As a result of these developments, the sub-division of flat rolled products into the older groups is becoming very confused because most of them can be produced by at least two distinct processes.

METHODS OF ROLLING SHEETS

Heavy and medium plates are rolled down from slabs which may be 2 ft. or 3 ft. in width and 3 in. to 6 in. in thickness, but very light plates and sheets are produced from sheet bars which vary from about 8 in. to 12 in. in width and $\frac{1}{4}$ in. to about 2 in. in thickness. In the process of hot rolling, single pieces can readily be reduced to about $\frac{1}{8}$ in. or

$\frac{1}{10}$ in. in thickness, but it is a very slow process to reduce single pieces to much less than this value owing to the rapid loss of heat and to the fact that the various parts of the mill deform elastically during rolling. For example, when the rolls are screwed down tight and a piece of metal less than $\frac{1}{10}$ in. thick is passed through them, the elastic deformation is so great that it is not possible to obtain a useful extension on the piece. Thus, the economic limit to the thickness of material which can be hot rolled in the old type of mill is about $\frac{1}{10}$ in. If material thinner than this is required, i.e., material in the normal sheet range, then several thicknesses must be placed together in order to obtain a bulk thickness of more than $\frac{1}{10}$ in. This method of rolling is known as pack rolling, and for very thin sheets as many as twelve or even sixteen thicknesses may be rolled at the same time. The pack is built up either by piling one on top of the other (priling) or by folding the pack on itself (doubling).

In all the older sheet mills the reduction to gauge was carried out hot, either in a single mill, or in two adjacent mills in train. Later on, when three and four-high mills were developed with backed-up work rolls and heavier construction, it became possible to carry out heavy reduction by cold rolling single sheets. Cold rolling requires more power than hot rolling, but against this fact it has the following advantages :

(1) It gives a better surface finish than hot rolling.

(2) The gauge can be controlled more accurately than by hot rolling.

(3) For full finished steel sheets the number of intermediate pickling operations can be reduced.

(4) A fine grained structure, together with a good ductility, can be obtained by a single annealing process.

REQUIRED PROPERTIES OF STEEL SHEETS

A number of factors other than physical dimensions need to be considered when evaluating a steel sheet and these include :

(1) Chemical composition and chemical properties.

(2) Crystal structure.

(3) Physical and mechanical properties.

(4) Surface texture and general surface condition.

(5) Flatness.

(6) Accuracy to dimensions.

(7) Uniformity of all the above factors :

  (a) within a single sheet.

  (b) within a batch of sheets,

  (c) from batch to batch.

Bessemer Converter.	Open Hearth Furnace.	Electric Furnace.
Liquid Steel.	Liquid Steel.	Liquid Steel.
	Ladle. (Alloys etc.).	
Ingot Mould.		Ingot Mould.
Square Ingot.		Slab Ingot.
Soaking Pit.		Soaking Pit.
Blooming Mill.		Slabbing Mill.
Cropping Shears.		Cropping Shears.
Bloom.		
Bar Mill.		Inspection & Dressing.
Bar Shears.		Slab.
Cooling Bank.		To strip Mill.
Sheet Mill.		
To Sheet Mill.		

FIG. 1. Flow diagram of liquid steel to semi-finished products.

Chemical composition is the most permanent characteristic of a steel sheet ; it is fixed when the liquid metal runs into the ingot moulds in the steel works and it remains almost unchanged during the subsequent processing. Crystal structure is influenced partly by the chemical composition and partly by the hot rolling, cold rolling and heat treatment processes. Chemical composition and crystal structure together, to a very large extent, control the physical and mechanical properties. The first three factors are very closely related, and together they might be described as the

metallurgical characteristics of a sheet. The remaining factors require little comment, as (4), (5) and (6) are readily observed by a general inspection, in contrast to the first three, which require special instruments or equipment to detect or measure them.

The final factor speaks for itself; it is the resultant of the variation in all the operations from steel making to the last operation on the finished sheet.

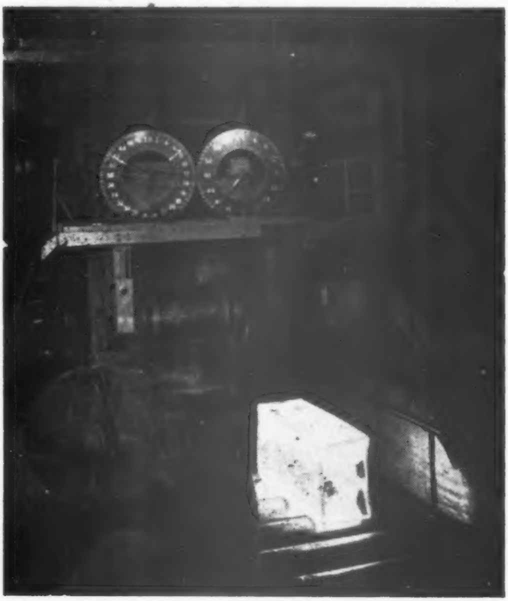


FIG. 2. Slabbing Mill.

STEELS USED IN THE SHEET INDUSTRY

The steels used in the sheet industry can be divided into four classes :

(*a*) The low carbon steels contain less than 0.15 per cent. Most of the sheets produced commercially are made from this class of steel.

Low carbon steels can be subdivided again into further types according to the degree of deoxidation.

(1) Rimming steels are not completely deoxidised, and during the freezing of the ingot there is a vigorous escape of gas which causes the impurities to segregate into a central core. In the finished sheet this impure core is sandwiched in between layers of relatively pure rim. This type of steel is favoured for sheets requiring a surface free from defects, together with good ductility. It is made in large tonnages for deep drawing sheets, and for this purpose the sulphur and phosphorus are kept as low as possible.

(2) Semi-killed steels usually contain some silicon and they are more completely deoxidised than the rimming steels. They also contain a higher percentage of phosphorus than the rimming steels, and as a result are less prone to give sticking or welding when rolled into thin sheets.

(3) Stabilised or non-ageing steels have been developed recently for deep drawing work in place of rimming steels. They are thoroughly deoxidised with aluminium, but other impurities are kept as low as possible. It is thought that the free aluminium stabilises the nitrogen.

(*b*) The medium carbon steels contain 0.15 to 0.40 per cent. of carbon and about 0.40 to 0.80 per cent. of manganese. They are generally made in the thicker gauges and find an application where greater strength is required than could be obtained from the low carbon steels.

(*c*) The silicon steels are used almost exclusively by the electrical engineering industry because of their special magnetic properties. These steels range in composition from about 0.10 per cent. silicon to about 4.5 per cent., and all other impurities are kept to a minimum.

(*d*) The alloy steels include nearly all the remaining steels used for sheet rolling. The most important are the chromium and nickel-chromium stainless steels, nickel steels, manganese steels, etc.

Sheet Bar.

Bar Shears.

Bar Heating Furnace.

Roughing Mill, Sheet Mill.

Mould or Breakdown.

Pack Furnace.

Sheet Mill.

Doubler.

Pack Furnace.

Sheet Mill.

Doubler.

Pack Furnace.

Sheet Mill.

Shears and Opening.

Hot Rolled Sheet.

Pickling Machine.

Cold Rolls.

Annealing Furnace.

Testing and Inspection.

Finished Sheet.

Pack.

Despatch.

FIG. 3. Flow diagram from sheet bar to finished sheet by hand mill process.

FIG. 4. Rolling in 2-High Hand Mill.

INGOT TO SLAB AND SHEET BAR

It is convenient to begin a description of the methods for producing sheets by starting with the liquid steel ready for pouring into the ingot moulds. When producing sheet bar the moulds might range from 10 in. square by 5 ft. high for a small ingot weighing 15 cwts., to 18 in. square by 6 ft. high for a large ingot weighing 3 tons. For the production of slab the ingot might be 40 in. by 20 in. by 7 ft. and weigh 7 to 10 tons. Beginning with ingots of these types, sheet or strip is produced by a series of rolling operations each one employing a mill of special design.

For the production of sheet bar, the ingot is reheated and rolled in a mill called a cogging or blooming mill to give a mass about 8 in. to 12 in. square, known as a bloom. After cropping the unsound ends, the bloom goes on, usually without further reheating, to another mill called a bar mill, to be rolled into sheet bar measuring 8 in. to 16 in. in width and $\frac{1}{4}$ in. to 2 in. in thickness. This is then sheared into lengths of 15 ft. to 18 ft. for convenience in handling, and after cooling it is transported to the sheet works. For the

production of slabs the ingot is reheated and rolled direct in a slabbing mill to give a slab, say, 36 in. wide and 4 in. to 6 in. thick. Where high grade sheets are required the slab is allowed to cool and the surface inspected and de-seamed or dressed, where necessary, with oxygen lances. Slabs rolled from rimming steel are usually cut into two or three parts, and those from the ingot top and bottom used for jobs of different types.

HAND MILL PROCESS FOR SILICON SHEETS The first step is to choose sheet bar of the correct chemical composition and size ; silicon steel for electrical sheets may vary from less than 1 per cent. to over 4.0 per cent. of silicon, and all other impurities must be kept to a minimum. The process is substantially the same for all silicon contents except that the temperatures of rolling and annealing are higher for the high silicon than for the low silicon material.

The size of the sheet bar is governed by the size of the finished sheet. If no doubling is done during rolling each bar becomes one sheet, but if the pack is doubled, each bar gives two sheets, and in the same way if the pack is doubled twice, each bar gives four sheets. As the bars are fed into the mill edgewise, the length of the bar becomes the width of the sheet, and as there is practically no lateral spread during rolling, the product of bar width (sheet length) and thickness remains constant right from the bar stage to the finished sheet. Thus, if bars of the correct size are rolled out to the correct length, the sheet will automatically be of the required thickness. The most convenient way of measuring this product, in the bar, is by taking the weight per unit of length, i.e., the weight in lb. per foot length, and sheet bar is usually graded in these units. In the case of sheets of low silicon steel 6 ft. long and 0.036 in. thick the bar weight per foot would be 9.60 lb. For sheets 8 ft. long and 0.016 in. thick, doubled once during rolling, the bar weight would be 11.40 lb. per ft., whilst for sheets 6 ft. long and 0.014 in. thick, doubled twice during rolling, the bar weight would be 14.90 lb. per ft.

The sheet maker must keep a very large number of sizes of bar in stock in order to cover all the combinations of length and thickness for each grade of steel, hence his desire to work in sheets of standard sizes as far as possible.

Having chosen the sheet bar of the required weight per foot, the next step is to cut the bar to the correct length, with appropriate scrap allowance, to give the required width in the finished sheet. The cut bars are then transferred to the mill and charged into the bar heating furnace in batches or heats of 16 to 32 bars, depending on the number of sheets obtained from one bar.

Sheet Bar.

Bar Shears.

Bar Pickler.

Continuous Bar Furnace.

3-Hi. Mechanised Mill.

Breakdown.

Breakdown Pickler.

Continuous Pack Surface.	
2 Hi. Mechanised Mill.	Cold Reduction Mill.
Shears.	Shears.
Hot Rolled Sheet.	Cold Reduced Sheet.
Normalising Furnace.	
Sheet Pickler.	
Annealing Furnace.	Annealing Furnace.
Temper Cold Rolls.	Temper Cold Rolls.
Roller Leveller.	Roller Leveller.
Inspection.	Inspection.
Finished Sheet.	Finished Sheet.
Oil and Pack.	Oil and Pack.
Despatch.	Despatch.

FIG. 5. Flow diagram from sheet bar to finished sheet (mechanised mill process)

Bar heating furnaces are usually coal or gas fired and range in temperatures from about 800° C. in the case of soft steel, to over 1,000° C. in the case of high silicon or stainless steels ; the atmosphere in the furnace is maintained as non-oxidising as possible in order to avoid excessive scaling of the bars. After suitable heating, two bars are removed from the furnace by means of tongs, dragged across the mill floor and deposited on the foreplate of the roughing mill. The bars are held one at a time in tongs and pushed edgewise into the mill ; at the exit side of the mill the catcher grasps the bars in his tongs and returns them, one at a time, over the top roll. The screws are adjusted and the operation is repeated until the bars are roughed down to less than $\frac{3}{8}$ in. thickness. This requires 1 to 3 passes for each bar according to the original thickness. The bars are then transferred to the sheet mill, which is adjacent, and given further passes singly until the thickness is reduced to about 0.125 in.

The two partly rolled bars are then placed one on top of the other, or matched, and the pair passed through the mill with the screws eased back for a further two or three passes. At this stage the pieces are about half the length of the finished sheet and they are known as breakdowns or moulds. They are separated, to allow air to come into contact with the inner surfaces in order to prevent sticking, and then charged into the pack furnace for reheating before further rolling. When suitably heated a pair of breakdowns is brought to the mill and given one pass, separated or opened, doubled over and the fold squeezed down tight in a doubling press. The doubled pack is now returned to the pack furnace for reheating, given a further pass in the mill, opened to prevent sticking, doubled as before, and again returned to the furnace.

It is common practice in many mills to shear off the first fold at the back of the pack before reheating. The reheated pack is then rolled to its final length by giving two or three passes, according to the required length and thickness. The hot pack is allowed to cool to a reasonable temperature for handling and sheared to size in the mill shears. The individual sheets in the pack are lightly welded together at this stage, and they require to be separated or opened. This is done by bending the corner of the pack with a pair of tongs and then by gripping each sheet in turn it can be pulled from the pack.

PICKLING

The next operation is pickling. This is carried out by immersing the sheets in about 5 per cent. to 10 per cent. sulphuric acid for about 10 to 30 minutes at 60° to 70° C. The sheets are packed in racks or cradles of acid-resisting bronze and agitated during the pickling process. Following the acid tank, the sheets are neutralised in lime water and finally

washed in running water. They then pass on to a drying unit, which usually incorporates a scrubbing unit as well. In this machine the sheets are scrubbed either with stiff brushes or with high pressure water jets and then passed through a hot water tank followed by a battery of gas jets or by a coke fire. After pickling and drying the sheets are passed through a two-high cold rolling mill to flatten and to improve the surface.

ANNEALING Annealing is the next operation and this is carried out by packing several tons of sheets on a flat or slightly curved base and protecting them from the atmosphere at high temperatures by means of a metal cover. The charge is then heated in a furnace for something like 30 to 60 hours at a temperature which may vary from 800° C. to 1,200° C., the furnace being heated with coal, gas or electricity. For the very high temperatures of annealing a special protective atmosphere is introduced under the cover.

After cooling, the sheets are unpacked from the annealing base, and samples selected for testing. If the material passes the tests satisfactorily it is subjected to a general inspection when defective sheets are rejected. The material is then ready for despatch to the customer.

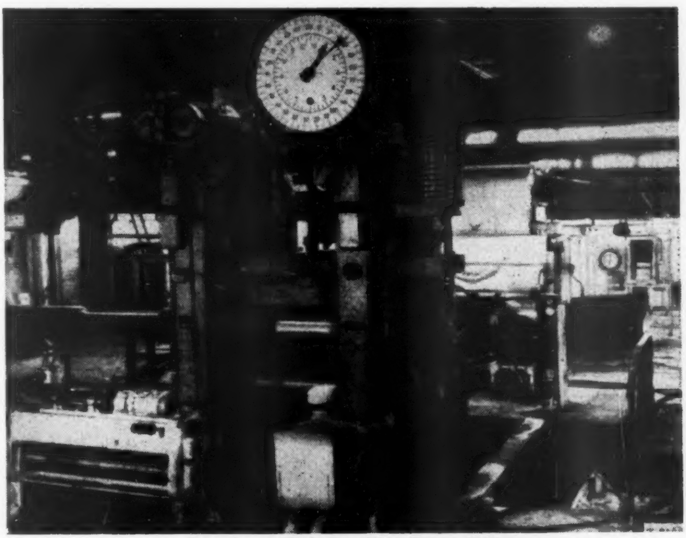


FIG. 6. 3-High Breaking Down Mill.

ROLLING SHEETS IN A MECHANICAL MILL Mechanised mills can be used to produce thin sheets similar to those just described, but as the main developments in sheet rolling were largely due to the demands of the motor car industry it seems fitting to describe the production of deep drawing sheets, such as those produced for motor car bodies immediately before the advent of the wide strip mill.

This description will also serve to contrast the technique of the sheet mill with that of the strip mill when producing the same grade of product. Sheet bar of suitable size to give finished sheets of, for example, 3 ft. by 7 ft. by 0.036 in. is chosen and cut to the required length. In many cases, before heating for rolling, the bars are pickled in order to remove the scale from the bar mill. The pickled bars are then charged into the bar heating furnace which is more completely mechanised than the one used with the hand mill. When ready for rolling, the bars are discharged from the furnace and conveyed to the mill, either by chain conveyors or roller tables. The three-high breaking down mill is provided with mechanical tables on both front and back sides for feeding the pieces into the bite of the rolls.

The process of rolling is similar to that already described. In the three-high breaking down mill each bar receives two passes singly, the bars are then matched and given two passes to bring the

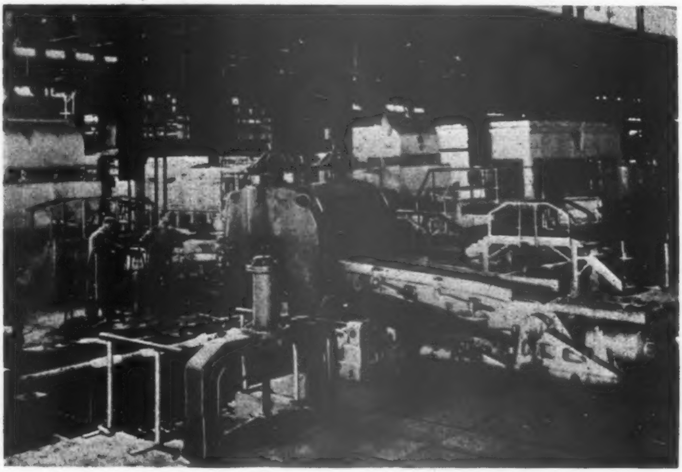


Fig. 7. Mechanised 2-High Sheet Mill.

breakdown to a length of about 40 in. to 50 in. The operation of the three-high mill is confined to the production of breakdowns from the sheet bar, and final rolling to gauge is carried out in a two-high mill also provided with mechanical tables.

When the best surface is required the breakdowns are pickled. This is carried out in a machine similar to that used for pickling the thin sheets from the hand mill, except that the drying machine is not used. In its place the last tank of the pickling machine is filled with boiling water sometimes containing lime in suspension. When the cradle is removed from this tank the breakdowns dry very quickly. The pickled breakdowns usually require some sort of treatment to prevent sticking ; this might involve spraying with oil or dipping in a tank of boiling water containing charcoal powder in suspension. The breakdowns are then charged in packs of four into the continuous pack heating furnace where they are heated to a suitable temperature for rolling. This temperature is kept as low as possible, usually not much above 700° C., and the atmosphere is maintained non-oxidising in order to prevent scale from forming and also to prevent sticking during rolling.

The heated pack is transferred by mechanical conveyors from the furnace to the mill, where it is given two or three passes to bring it to the required length and thickness. The packs are sheared, opened whilst still fairly hot and then transferred to the heat-treatment department. Here they are passed, one or two at a time, through a continuous normalising furnace where they reach a temperature in excess of the upper critical point (about 950 to 1,000° C.) ; during normalising the furnace atmosphere is controlled so as not to cause excessive scaling. The object of normalising is to remove the rolling strains and to develop a small and regular grain structure.

Following the normalising process the sheets are pickled and then in some cases given a light pass in a cold rolling mill to flatten and also to improve the surface. They are then subjected to a low temperature box anneal at about 600 to 650° C. in order to remove the strains left behind after the relatively rapid cooling in normalising. After annealing, the sheets are given a pass in a two-high cold-rolling temper mill in order to prevent the formation of stretcher strains during pressing ; they are then roller levelled, inspected, oiled and packed for despatch.

DEVELOPMENT OF COLD REDUCTION METHODS

The demands of the motor industry for a better sheet product for body press work were not entirely met by the process just described, yet it was obvious that the hot rolling of sheets in packs had just about reached its limit, particularly in regard to the surface. For example, from the sheet bar to the finished sheet the following processes were

FIG. 8. 3-Stand Tanden Cold Reduction Mill for sheets.

involved : two reheatings for rolling, three pickling operations, two heat treatments—as well as two or three cold rolling or flattening operations, quite apart from the rolling itself. The development of cold rolling mills with backed up rolls, together with the demands for better surface finish, directed attention to the cold rolling of sheets to final gauge. This had further advantages mainly in reducing the number of pickling operations and also in yielding a satisfactory grain structure by one annealing operation, without the use of normalising.

By this system the sheet bar was hot rolled in a two-high or three-high mill to give breakdowns about double the finished sheet thickness, i.e., about 0.06 in. to 0.09 in. thick. These were pickled and then cold reduced in single pieces to about 20 gauge. They were then sheared, annealed, temper rolled and finished as described for sheets produced by hot rolling.

Meanwhile developments were taking place in the continuous rolling of sheets and also in the continuous rolling of wide strip. Both these systems involved the use of cold rolling to final gauge and differed from one another essentially in the fact that in the first case, rolling, etc., was carried out on a series of short pieces whereas in the second case, rolling and several other processes also were carried out in the form of long bands or strips. In the end, strip rolling proved to be more successful than continuous sheet rolling,

Slab
Reheating Furnace
Roughing Mill
Delay Table
Shears
Finishing Mill
Hot Rolled Strip
Hot Coiler
Pickling Line
Cold Strip Mill
Cold Reduced Strip
Shearing Line
Annealing Furnace
Temper Mill
Roller Leveller
Finished Sheet
Inspection
Oil and Pack
Despatch

Scale Breaker
Broadside Mill
Slab Squeezer
Shears
No. 2 Roughing Stand
No. 3 " "
No. 4 " "

Scale Breaker
No. 5 Finishing Stand
No. 6 " "
No. 7 " "
No. 8 " "
No. 9 " "
No. 10 " "

Uncoiler
Squaring Shears
Stitcher or Welder
Looping Pit
4 Pickling Tanks
Rinse Tank
Drier
End Shears
Recoiler

FIG. 9. Flow diagram from slab to finished sheet strip mill process.

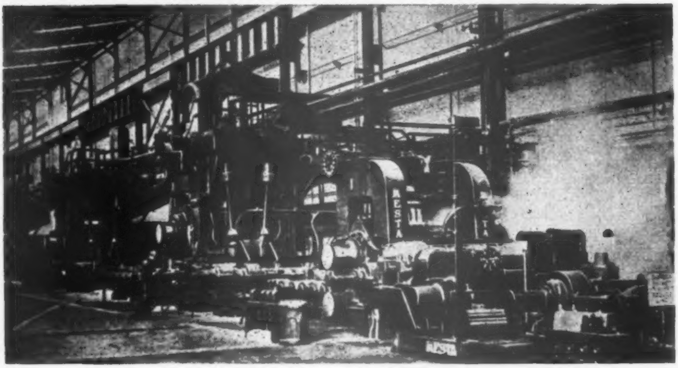


FIG. 10. Strip Mill — Roughing.

and it has now affected a complete revolution in the methods for sheet production. In America, for example, nearly all the high grade sheet material is produced in this way, and about thirty mills have been constructed with a potential output of over 15 million tons a year. In this country two mills have been built and a third is proposed, probably to be followed by others.

FIG. 11. Strip Mill.

FIG. 12. Front end of pickling line.

FIG. 13. Three stand cold strip mill.

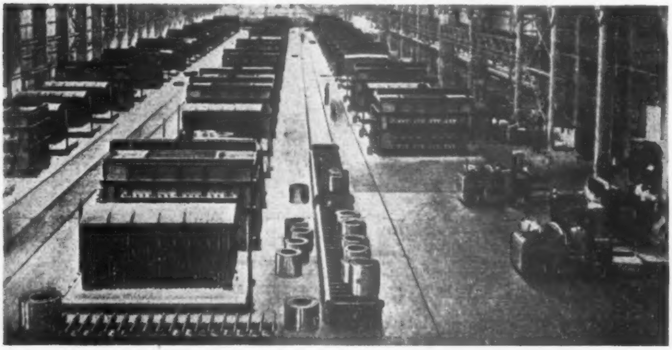


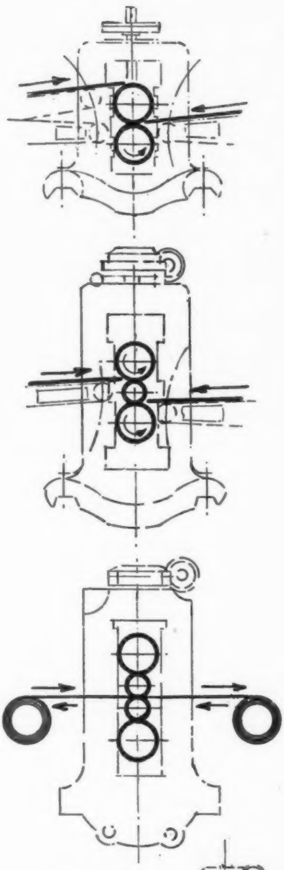
FIG. 14. Modern Annealing Shop.

THE STRIP MILL PROCESS

The starting point in strip rolling is the slab. As already described, the usual practice is to allow the slab to cool after rolling from the ingot, and then inspect and dress where necessary. The slabs are heated for rolling in a gas fired recuperative furnace of the continuous "pusher" type capable of heating them to a temperature of about 1,200 to 1,250° C.; the slabs are discharged, one at a time, and conveyed by means of a roller table to the roughing mill. This consists of a series of two-high or four-high stands in tandem; it is designed to reduce the hot slab from 3 to 6 in. in thickness to a plate or breakdown of the order of 0.75 in. in thickness. Roughing mills vary a good deal in design and layout, but the case to be considered can be taken as typical of a mill about 80 in. wide. The first unit is a two-high scale breaking stand whose function is to apply a light reduction in order to crack the heavy scale formed during reheating; the scale is then removed by high pressure water jets. The next stand is known as the broadside mill, and its main purpose is to increase the width of the slab when strip is required wider than the available slab width; turn-tables are provided both in front and behind this mill.

The broadside mill is followed by a slab squeezer to adjust the slab width to a value a little greater than that required in the finished strip. At the same time it serves to remove any bow or camber from the side of the slab. A slab shear is sometimes provided after the squeezer in order to trim the leading end of the slab. Three further stands of roughing mills follow, each preceded by vertical edging rolls to control the width.

High pressure steam or water jets are provided between each edging mill and the roughing mill. The distance between the



CLASSIFICATION OF MILLS

THE TWO HIGH MILL, as used for sheet rolling, is non-reversible, and the bottom roll only is driven. The top roll is not suspended and jumps up to the screws when the piece passes through the mill, hence it is often described as a "Jump Mill." The piece is passed between the rolls in one direction and returned over the top roll for further passes, as shown by the arrows.

THE THREE HIGH MILL. In this mill the top and bottom rolls are driven, and are of larger diameter than the middle roll, which is driven by friction from the other two. Small diameter rolls require less power for rolling but of course they deform more than larger diameter rolls. In the 3-High Mill the large diameter rolls at the top and bottom support or "back up" the small diameter middle roll. Every pass through the 3-High Mill is a working pass.

THE FOUR HIGH MILL has become the mill par excellence for heavy reductions, especially for strip. The two small diameter middle rolls are driven, and the piece passes between these two rolls. The large diameter top and bottom rolls merely back up the work rolls and are driven by friction from those rolls. Four High Cold Reduction Mills may be reversing or non-reversing. Usually the reversing mills are single stand with power driven coiling gear on either side of the mill. The non-reversing mills are usually arranged in tandem with power driven coiling gear at the exit end of the mill only.

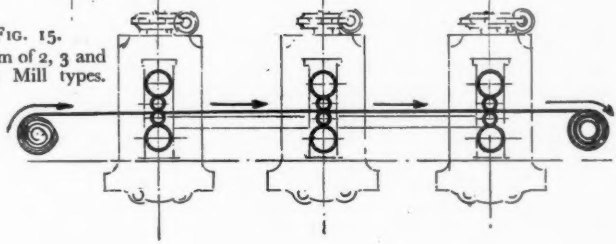


FIG. 15.
Diagram of 2, 3 and 4-High Mill types.

various stands progressively increases from about 30 ft. to 90 ft. so that the breakdown is never in more than one mill at a time; the slab or breakdown is conveyed from one mill to the next by roller tables. Following the last roughing stand is a long roller table, known as the delay table, where the breakdown may be held for a period of time in order to control the temperature of the strip when it leaves the finishing mill. The latter consists of a two-high scale breaking mill and six stands of four-high mills in tandem. These mills are only about twenty feet apart so that in contrast to the roughing mill, the strip is in several stands at the same time. The strip leaves the last stand of the finishing mill at 1,000 to 2,000 ft. per min. and is carried on the runout table to the hot coilers. The coiled strip is allowed to cool and may remain in stock for some little time before it is pickled. Pickling is carried out in a continuous pickling line where the strips are uncoiled and joined end to end to give a continuous band of metal through the acid and rinse tanks. The individual parts of the equipment are the uncoiler, the squaring shears, the stitcher or welder for joining the coils together, the looping pit which permits an accumulation of strip whilst shearing and stitching takes place, three or four pickling tanks, the rinse tank, the drier, the end shears and finally the recoiler.

The pickled strip is cold reduced to the final gauge on four-high tandem mills which may have either three, four or five stands in line. The three stand mill is common for material of about 0.040 in. thickness which is rolled from hot strip about 0.080 to 0.100 in. thick. For thin gauges such as used for tinplate five stands are common, beginning with strip about 0.050 in. thick. Each mill is individually driven by an electric motor and the strip leaving the last stand is coiled under tension on a power driven coiler.

Sometimes the strip is annealed in coil form, but a large amount is sheared to size on a continuous shear line and annealed as sheet or cut strip. Annealing is carried out in batch furnaces which may hold a charge ranging from 30 to over 100 tons. Two types of furnace are in common use; these are known as the "portable cover" type and the "in and out" type. The "portable cover" furnace is most common; in this type the charge is packed on a fixed base, protected by a light cover from oxidation at high temperatures and heated by an outer cover which is fitted with radiant heating tubes on the inside. The "in and out" type consists of a fixed furnace with portable base and cover. In all modern annealing plants the charge is protected from oxidation by introducing a special gas atmosphere into the inner annealing cover. Annealing temperatures vary from about 650° to 730° C. and times of heating and soaking from about 35 to 80 hours. After cooling, the coil or sheet is temper-cold-rolled, roller-levelled,

inspected, oiled and packed for despatch. Cold-reduction and temper-mills, which are producing material for deep drawing purposes, usually have their work-roll surfaces shot-blasted to give a dull or matt finish to the sheet.

In this country, at the present time, hand mills, mechanised sheet mills and strip mills are operating side by side. In America nearly all the hand mills have disappeared and only a few mechanised mills remain with the strip mills. The hand mills will almost certainly disappear in this country within a few years—mainly because of the difficulty of obtaining operators. However, it is not yet possible to roll all grades of sheets on a cold strip mill so that the mechanised sheet mill is likely to remain for some time to come.

THE APPLICATION OF TUNGSTEN CARBIDE CUTTING TOOLS

By C. EATOUGH, B.Sc.(Tech.,) M.I.Mech.E.,
and H. ECKERSLEY, M.I.P.E., M.I.Mech.E.

Presented to the Coventry Section of the Institution, October 15th, 1948.

PART I. (*Mr. C. Eatough*)

I understand that I am to deal with the machine tool side of the problem. My friend, Mr. Eckersley, will deal with cutting tools. This cannot be a rigid division and there is bound to be a certain amount of overlapping, but I will try not to trespass on Mr. Eckersley's territory more than necessary.

The underlying idea of using tungsten carbide on a cutting medium is to reduce the cost of production, and as on chip forming machines it is *feed* that determines the rate of production and not *speed*, the object is to increase the rate of feed. You might ask—why use tungsten carbide to increase the rate of feed, which we could do very well with high speed steel? Taking the latter course invariably leads to a rougher degree of surface finish and loss of accuracy of the component being machined.

By the use of tungsten carbide to increase the cutting speed, we can increase the rate of feed and still maintain relatively thin chips and thereby improve both the surface finish and the accuracy of the product.

It is on these lines that tungsten carbide has been developed for machining operations and this has led, in the last few years, to great developments in the relatively light high speed machine tools. This growth in the light machine tool industry has been brought about chiefly by the demand of the light industries, such as domestic appliances, wireless trades, and automobile manufacture, etc. You will note that the machines have not created the demand, but have been developed to meet it.

The method of increasing feed by means of high cutting speeds is not free from troubles directly due to the fast speeds, but the advantages in the way of increased production usually outweigh the disadvantages attributable to rapid speed of cutting. Figure 1 shows the important difference between high and low speed cutting. The tools shown have negative rake, but this is not material to the point I wish to emphasise. Both tools are shown

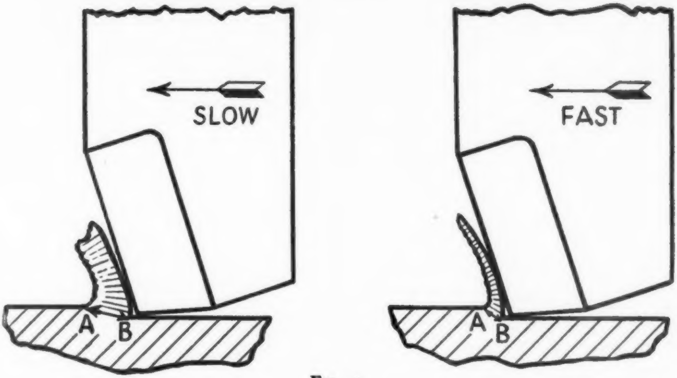


FIG. 1.

operating at the same depth of cut on similar materials, but one is cutting at a slow speed. The very great difference in the thickness of the chips will be noticed.

The major work done in removing a chip from metal in the manner shown is expended in shearing and the two dimensions A-B form a measure of the shearing forces involved. The thin chip flowing fast is typical of carbide cutting technique. The small dimension A-B associated with high cutting speeds indicates low stresses both on the component being machined and on the machine, and in turn good surface finish and high accuracy can be expected.

Although machines for high speed cutting may have to be provided with large motors, the stresses involved may still be quite low, since relatively thin chips can be produced even at high rates of production.

EFFECT ON MACHINE TOOL INDUSTRY The developments of H.S.S. many years ago led to a complete revolution of chip forming machines, but introduction of tungsten carbide did not have anything like such a great impact on the machine tool industry—simply and solely due to the brittle nature of this material. The application of tungsten carbide is not so universal as was H.S.S., and on certain forms of machining, even today, it still gives us quite a lot of trouble, brought about by lack of toughness of the material of the cutting tool.

I am not apologising in any way for the new material ; we have still a long way to go in its development. But its future is assured, even on present performance, and you must understand that it is still very young.

One trouble, from the machine tool angle, is that the present-day user of the machine tool has been brought up on high speed steel technique. We have to teach many operators to forget the old methods. My experience is that we do better with carbides with "green" operators than we do with the average skilled man.

One essential of this new material was that success could only be obtained with high speed cutting. As soon as this was realised the material jumped ahead in many applications. The high speed cutting gives the machine tool man many headaches in spite of reducing the load on the machine and maintaining thin chips.

High speed of cutting leads to very high operating temperatures at the tool nose, which is always in direct contact with the work and chips ; but tungsten carbides are greatly resistant to softening at high temperatures. Unfortunately Nature, throughout all the cutting materials I know, has laid down one very rigid rule—the more a material maintains hardness at high temperatures, the more it is deficient in toughness.

Full appreciation of the brittleness of tungsten carbide is essential for success in its application. The technique of increasing the speed has led to a very great increase in the horse-power absorbed by the machine, and in many examples we are machining at 6 to 8 times the corresponding speeds previously used with H.S.S. tools.

Carbides present difficulties when form cutting under certain conditions. Chips are produced at a fast rate and unless we give these chips ample opportunity and time to escape we encounter serious troubles. This is one of the chief reasons for the lack of success in tools such as threading tools, where heavy chip pressures result in the restricted area of flow. Although we are increasing the *main* cutting speed of machines, we cannot increase the lower speeds, where forming has to be done at present with H.S.S. ; the machine tool problem is then to provide ample power at high speed increasing the speed range of the machine at the high speed end and maintaining, if not reducing, the speed range at the low speed end.

The aircraft industry for some time has been calling for more difficult steels from the machining point of view and screwing speeds, even today, are steadily declining.

HIGH SPEED MACHINING

This wide speed range leads to many difficulties. Machine tool buyers insist on a very wide speed range, so that their machines will be versatile and adaptable to all classes of production. The speed drive becomes costly, complicated, and bulky, and it makes one wonder whether the day of the general purpose machine as we know it is gradually passing. The ability to select instantly any one of a wide range of speeds is very nice, but can cost a lot of money. There is much to be said

for the simpler, more specialised machine, where large quantity production is envisaged.

The fortunate point about high speed machining with carbide tools is that with high speeds the stresses are proportionately low, and frequently are appreciably lower than when machining with high speed steel. This emphasises the ability of the machine at the high speed end of the range to run fast, rather than have plenty of strength, still assuming of course that we have rigidity and freedom from vibration at these high speeds.

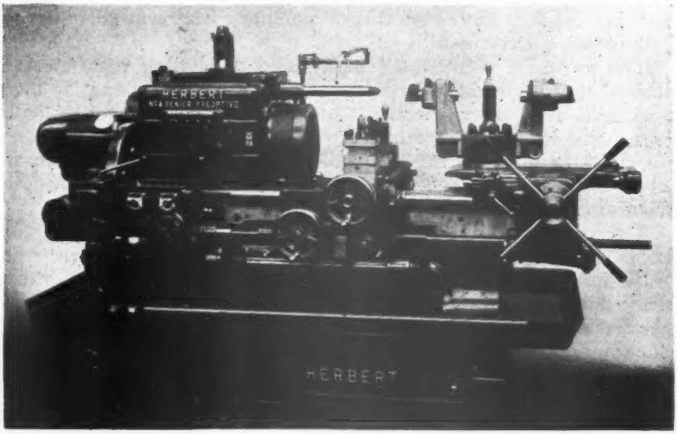
The average machine tool today is occupied in actual cutting for about 20 per cent. of its working life—and 80 per cent. of its time is occupied in maintenance, speed changing, etc., and it is in this field that the machine tool designer is looking for increased performance. On 20 per cent. cutting time, the increase in production which can be obtained by slight increase of speed may not be very high as compared with what might be obtained if the remaining 80 per cent. can be reduced.

Some saving can be achieved by easier and quicker methods of speed changing. There are three main systems in use—these are electrical, hydraulic, and mechanical, in various combinations.

There are types of general purpose machines, such as the combination turret lathe, which have special operating requirements. The combination turret lathe frequently requires high power not only at the top but also at the bottom of the range for dealing with relatively large diameters. Other machines require high power at the high speeds but very little power at the low speeds. Bar machines are typical of this type.

The machine designer has to provide ample power at the speeds where it is wanted, and every type of machine must be considered on its merits. Much has been said about infinitely variable speeds and their benefits, and although in actual theory economical cutting speeds are somewhat critical, in practice I cannot justify the application of stepless speed changing for the average machine tool drive. My feeling is that there will be a great simplification in the work drives of machines, even if this restricts the range immediately available for rapid changing. There is a very convenient arrangement whereby slip gears can be inserted to give one or two speeds, by friction clutches, or electrical changes, and still leave a very wide range available by using alternative gears. Here we have a case of flexibility of speed, but only part of the wide range is available at any one time for operational use.

GENERAL PURPOSE DESIGN A modern general purpose design is shown in Figure 2. The machine is a No. 4 Senior Preoptive Head Capstan Lathe, and has been designed to make speed selection rapid and effortless. The head has a wide speed



F.G. 2.

range from 42 to 1000 r.p.m. in eight steps, all of which are instantly available. The changes of speed are obtained by means of electrically operated friction clutches and all take place without stopping the spindle so that cutting is continuous. Speeds are preselected by the operator turning the four-spoked wheel, seen on the front of the headstock, to the required position, when the selected speed can be engaged by finger tip pressure on the small knob in the centre of the selection wheel. The machine is used for general purpose work and consequently may be called upon to deliver plenty of power throughout the whole speed range.

Of necessity the complications required to deal with large powers over a wide range with extreme ease of control tend to increase the cost of the machine, and for large quantity production work of a specialised nature, the various refinements are not always required. Where, however, frequent changes of speed are wanted, the design shows great economies in production. The motor control is by push buttons giving Stop, Forward, Reverse, and Inch—all being available on any speed.

The ease of headstock control combined with electric chuck operation gives freedom from operational fatigue. The chuck control lever can be seen above the feed box and below it to the left is a small rotary switch which has three positions, giving three different chuck grip pressures. The designer of this machine has enabled the full advantages of modern cutting tools to be obtained by the provision of ample power and rigidity, and at the same time achieved a considerable saving in operational effort.

A more specialised machine is shown in Figure 3. This is No. 2 S Capstan Lathe intended for large quantity production work, and has a very wide range of spindle speeds which are obtained by means of slip gears. Of the speeds covered two only are obtainable at any set-up, and these are controlled by friction clutches and as such can be operated without stopping the spindle. Electrically controlled Stop, Start, and Reverse are available.

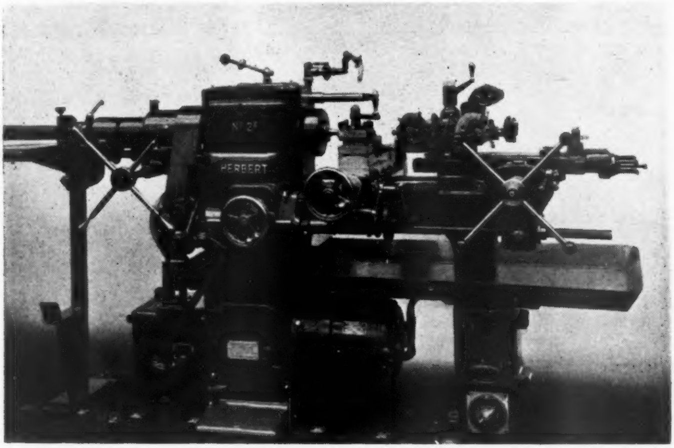


FIG. 3.

As the machine is intended for high speed work, it is important that expansion of the headstock members due to temperature rise do not affect the machine alignment and for this reason the headstock unit has been simplified as much as possible. Basically it consists of a spindle, on which is mounted a driving pulley and front and rear anti-friction bearings. The driving box is attached to the left hand box leg, and any members of the drive which are likely to get warm in service, being remote from the spindle mounting, cannot affect its alignment.

A TANGENTIAL TOOL

Figure 4 shows a tangential tool with typical chips. This type of tool is becoming the standard tool for bar work. It is applied to the work tangentially to give maximum rigidity and freedom from vibration. The tungsten carbide tip acts as a chip curler and as a result, we get chips such as you see lying at the bottom. These chips have two very great advantages ; one is that they are very compact for their

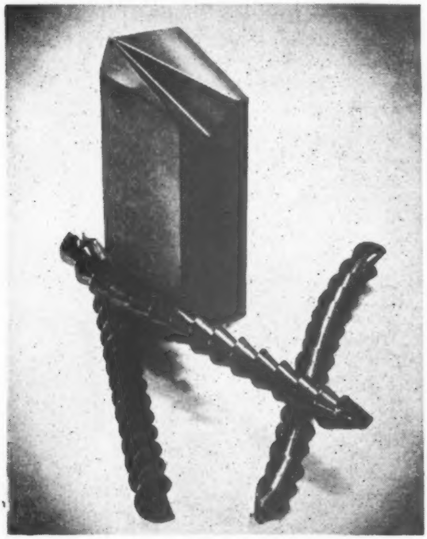


FIG. 4.

weight and therefore not bulky, and furthermore, due to their conical formation, they are particularly safe, because half of the dangerous edges are hidden.

Figure 5 shows the box tool on which it is used ; the rollers support the work and it is very important that these rollers are not interfered with in any way by chips getting between them and the work. This is an example of deliberately encouraging chip continuity, in order to get the chip clear away from the work and the rollers.

Figure 6 shows a machine having special power requirements. It is designed for producing work from bar and as such the maximum diameter of work is normally determined by the size of the hole through the spindle. The speed range has to be such as to give satisfactory turning speeds on all diameters of bar up to the maximum, and high power requirements have to be met over this range. In addition, slow speeds have to be provided for forming and threading, but on these speeds low power only is necessary.

The machine shown deals with bars of 2 in. maximum diameter. The two-speed motor is nominally $7\frac{1}{2}/2$ h.p. The main turning work uses the high speed of the motor where $7\frac{1}{2}$ h.p. is available, and the slow speed giving 2 h.p. is used for threading and forming.

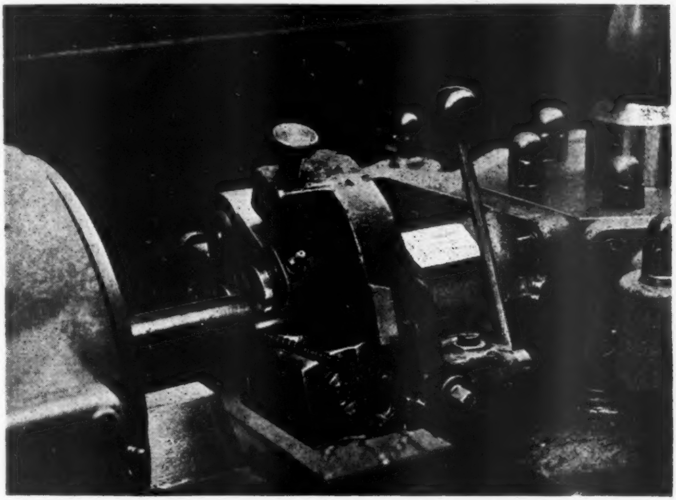


FIG. 5.

FIG. 6.

Due to the intermittent nature of the average turning operation, the motor at the high speed is capable of delivering 10/12 h.p. at the tool nose. The high motor power is available throughout a spindle speed range of 80 to 1520 r.p.m. in eight steps, and the low power over a range of 20 to 71 r.p.m. in four steps. The powerful double-toggle chuck is electrically operated, as also is the bar feed mechanism.

BAR TURNING MACHINES

Bar turning machines operating with carbide tools present a problem in the design of the bar feed. The long bars are rotating at high speed and have to be prevented from whirling. On the machine illustrated, special guiding means are provided to avoid whirling and to minimise noise. The main turning operations of the hexagon lathe are carried out by chipstream roller box tools. On these box tools the rollers run on needle roller bearings, as the rotational speeds are high to suit carbide cutting conditions. The corkscrew-like chips which, as previously stated, are encouraged to keep in long lengths to avoid roller interference, cannot be allowed to run uncontrolled, otherwise they become a danger to the operator. They can be broken into convenient lengths by means of the device shown in Fig. 7.

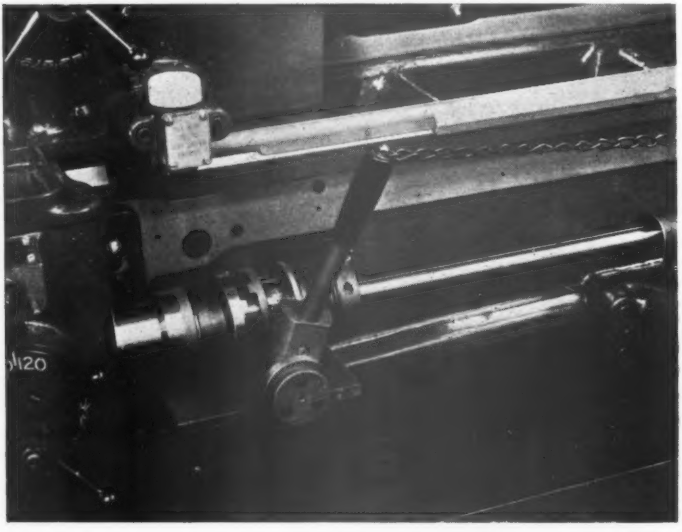


Fig. 7

This is known as the Chiprupter and in the form shown consists of a means of interrupting the lathe feed by disengaging a dog clutch on the shaft driving the feed train. The clutch is operated normally by the operator pulling on the chain whenever a break is required. The clutch is re-engaged automatically as it is spring loaded. The device could be arranged for automatic operation,

but it is usually more convenient to leave it to the operator, who uses it only as and when required to exercise control, to determine suitable lengths of chips to fall into the machine tray and not on to the floor. The chain pull necessary is only a few ounces and the operator stands well back out of the way of the hot chips.

Fig. 8 shows a general view of a special purpose centre lathe designed for carbide tools. The two-speed motor of 9/2 h.p. gives a very wide speed range by means of slip gears. Each pair of gears permits a choice of two speeds by push button control. The main turning work is done by a tangential tool, at the rear of the cross slide. The front of the cross slide carries a square turret in which are mounted tools for facing, chamfering, nicking, etc. Longitudinal feeds are tripped by a six-position stop-bar, and the hand-traversed cross slide is provided with a front position stop-bar. As the machine is not intended for drilling, screwing, or reaming, all cutting is done dry with carbide tools and no suds pump is provided.

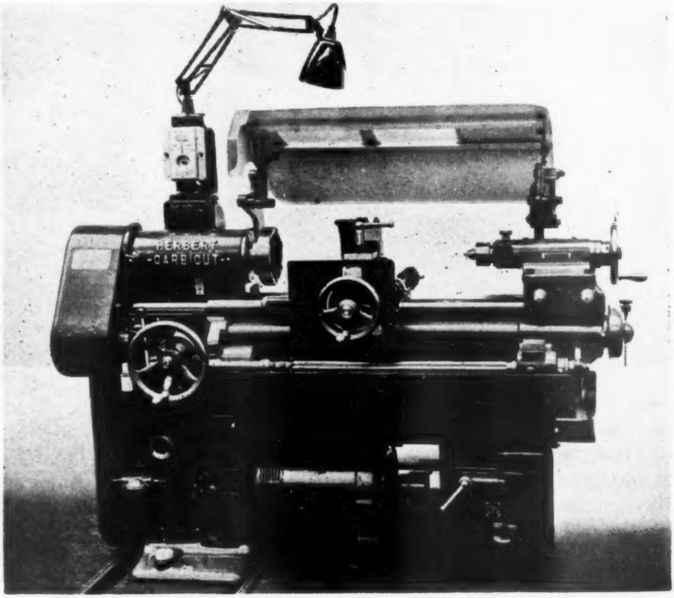


Fig. 8.

FIG. 9

The simple headstock with the remote driving box is another example of the elimination of heat producing units from parts of the machine which might cause alignment troubles. Chip disposal on this machine is different from machines using roller box tools. On the Carbicut machine, chips are led to the rear out of the way of the operator and are easily broken by being directed into a steel box forming an abutment. This device breaks the chips into six-inch lengths which readily fall into the chip tray.

Quick power traverse in both directions is available for the longitudinal movement of the saddle, and this feature together with the easily operated feed control and speed push buttons saves an appreciable amount of non-cutting time.

The Carbicut lathe is not fitted with a Chiprupter since it is permissible to break the corkscrew-like chips by leading them into an abutment. As each break occurs, with this device, the coil nearest to the tool nose increases in diameter before breaking. On the Carbicut lathe this point is not important, but it could not be permitted with a roller box tool, as the enlarged coil would damage the surface of the adjacent roller.

Figure 9 shows a rear chipstream tool used on the rear of the cross slide of a capstan or combination turret lathe. As with the Carbicut, an abutment breaker is used.

The general problem of chips disposal and control is of very great importance and presents many difficulties due to the wide range of materials, speeds, feeds and cutting depths which have to be covered. The matter is receiving a lot of thought, as not only is machine efficiency involved but also operational safety.

USE OF COOLANTS

Coolants show a little advantage in tool life when used with carbide tools, but as a rule the disadvantages attending their use outweigh the advantages. One important use of coolants is to quench the hot chips and so minimise any burning which might otherwise occur if a chip should strike the machine operator.

Where H.S.S. tools such as dies, reamers and drills are used with carbide turning tools on multi-tool layouts, the use of coolants may be necessitated by the H.S.S. tools and such applications should have a plentiful supply.

PART II. (Mr. H. Eckersley)

Mr. Eatough has very ably covered the ground of carbide application from the machine tool makers' point of view, and also from the users' point of view to some extent, but there are one or two points which require some elaboration.

In the first place, I have a very great deal of sympathy with Mr. Eatough in his endeavour to provide a machine tool which can fully exploit carbide, because generally speaking the fellow who has to design the machine tool does not know what that machine tool has to make, and consequently the machine must be designed

to take a very considerable range of products. In spite of that, when the user gets it he invariably expects the machine to do very many more jobs than those for which it was designed. That is when the Tooling Engineer has to make the best of the limitations of the machine, the limitations of the job, and sometimes, the inadequate knowledge of the people who are using the machine.

This is not to deprecate the work which Production Engineers have themselves done in the utilisation of carbide tooling. Without the experience of the user of carbide tools, neither the machine tool designer, nor the tool designer and tool maker, can make very much progress.

FUNDAMENTAL PRINCIPLES

There are a few fundamental principles which it is necessary to appreciate before the user can even benefit from some of the features of which the machine tool designer takes care. Mr. Eatough has stressed the necessity to get the chips away at high speeds, but there is another principle involved in the use of tangential tools which I think is more important still—that is the advantage of stiffness where stiffness can be controlled. I contend that since the workpiece is bound to be variable in any factory, on any particular type of machine, and since the machine tool is designed for use in many factories employed in a variety of products, the workpiece should ideally be the only limiting factor in determination of metal removal rate.

I would like to stress here the importance of considering the tool design prior to the machine being designed at all.

We all of us have in our minds, either by training or by tradition, the fact that high speed steel tools are of a particular section for a machine of a particular size, and it is unfortunate that the machine tool designer has those provisions in his mind. The last thing he thinks about is what size of cutting tool is going to be used and in what form it is going to be presented to the job.

It is necessary to consider the effect of deflection more carefully when cantilever types of tool are used. Of course, if we stiffen up the tool section to produce the desired resistance to bending, or twisting, then we may have an unwieldy size of tool, but if we employ the tangential type of tool, we are then applying our thrust on to the end of a column, instead of on a cantilever, with considerable gain in tool rigidity.

A typical and well-known example of this form is the tangential roller-box tool, which was introduced for carbide tooling about 1935. It was almost impossible to obtain any results with carbide tipped cantilever roller box tools, because the chips caused fracture of the carbide tip.

Mr. Eatough stresses that the brittleness of carbide imposes limitations in application to many forms of tooling, but I would remind you that the tool designer and the tool maker have to accept machines as they are and not as they might be and consequently, some compromise in tool and carbide design and specification is sometimes necessary. Because knowledge is now being acquired at an accelerating pace, better understanding and co-ordination of machine tool and cutting tool design is being achieved.

Many firms now use tangential chasing tools, thread cutting tools, parting tools and a variety of other tools of that type ; but we must not concentrate too much on turning. There are many other machining operations in engineering production which require a variety of types of tools and we have to consider them all.

It is necessary, in addition to removing metal from the outer surface of a workpiece, to produce holes, slots, flats, squares and other shapes. Facing cuts on chucking lathes present a problem to many people due to variation in cutting speeds from outside to inside.

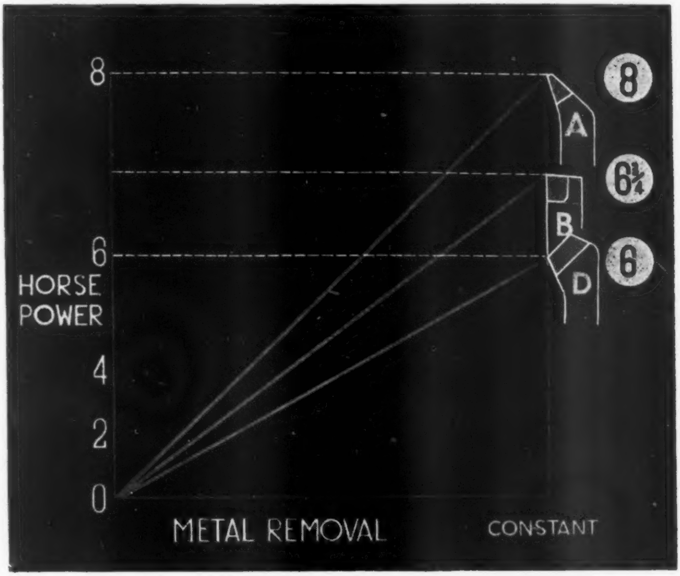


FIG. 10.

CHIP FORMATION

I would start my illustrations with a short discussion on the effect of tool shape on chip formation and whilst, in the main, amongst the half-dozen illustrations which I have, the turning tool is shown, I would like you to picture in your minds the same principles applied to any type of cutting tool, including reamers, milling cutters, drills and other types of tools for metal removal.

In Fig. 10 the top tool is a round nose tool ; the middle tool, a normal type of bar tool ; and the bottom tool, a tool with a 45° approach angle. The horse-power consumed by the tool at the top is 8 in this case, and under the same conditions, the bar type takes 6¾ horse-power, while the tool with the 45° approach angle takes only 6 h.p. Now, this difference arises from the fact that in order to produce a round chip of any kind, the horse-power consumed in bending the chip over the surface of the tool is far greater than the horse-power required to bend a flat chip, as in the case of the bar tool. Where a flat chip is produced the horse-power consumed in obtaining that chip is very much less—1¼ h.p. less for this case ; but with equivalent feed the thinner chip produced by the tool with a 45° approach angle reduces the total horse-power taken to only 6.

It may not always be desirable to have a very thin chip. There is a minimum chip chickness which produces maximum efficiency of metal removal. Lengthening of the cutting edge certainly reduces the unit cutting pressure on the tool for the same feed and depth, and yet the area of cut remains unaltered. A reduction in unit pressure reduces the risk of breakage. The use of a round nose tool for general turning work is therefore to be deprecated, because it wastes horse-power. Fig. 11 illustrates this point.

Here we have an approach angle of 45° and the black end is the area of cut. Where heavy cutting pressures are involved, the use of an approach angle means that carbide can be used where otherwise it may be considered completely unsuitable. One of the toughest machining jobs is the turning of chilled iron rolls. These materials are extremely hard, as you know, and the pressures imposed upon the tool are amongst the highest experienced in any metal removal operation.

The practice in turning chilled rolls has always been to use a tool with an extremely long cutting edge, maybe 4 in., and whilst only a shallow depth of the chilled surface must be cut—about ⅛ in.—it would be quite impossible to use orthodox bar turning methods in such a case.

The same principle applies in milling. Since milling is purely interrupted cutting, it is necessary to spread the load, in so far as it is possible to spread it, in order to get increased feeds and so show economy in carbide tooling. With all orthodox types of

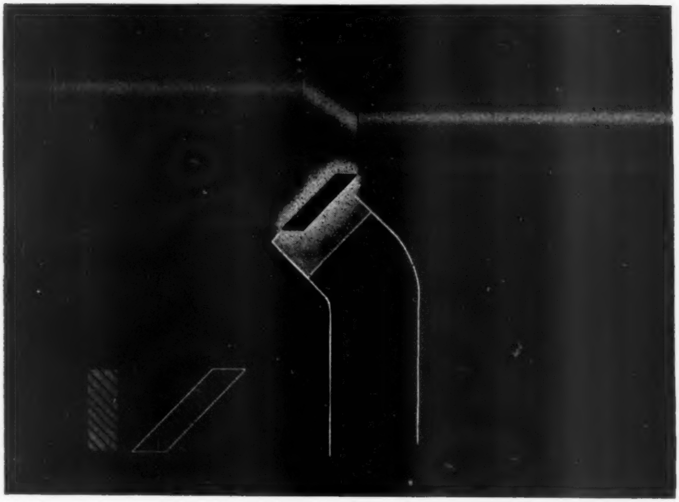


FIG. 11

milling, as in the case of a roughing tool, an angle of not more than 10° to 15° is quite usual, and an angle of 15° actually produces the maximum number of work-pieces per regrind, as compared with other forms of tools.

When very heavy cuts on milling require to be taken, it may be desirable to follow the chilled roll turning practice by lengthening the cutting edge considerably, by adopting an approach angle of something more than 45°. This is only possible on that kind of work where the work-piece in itself is rigid.

The thin job requires, more often than not, a tool which will induce a direction of cutting pressure which will not have the effect of causing bounce between the tool and the surface being machined. In light shaft turning, where the diameter is small in relation to the length, we are all familiar with the problems of whip at various speeds. The pressures on the tool must be always parallel, in this instance to the work axis, in order to reduce as much as possible the vibratory effect of the cutting load.

USE OF NEGATIVE RAKE

We will now consider the rakes to be used. First, I would like to disillusion some minds on the question of negative rakes. The only reason for a negative rake is to resist the inclination of the chip to break the cutting edge of the tool.

Where the cutting pressures are light, as in the case of iron, some bronze alloys, aluminium alloys, and mild steels, there is not the slightest gain in using negative rakes. The negative rake is intended to produce a change in direction of chip pressure, to take care of the cutting edge, and it does certainly absorb a great deal more horse-power ; but negative rakes are only necessary on those materials where the machinability figure is so low as to produce pressures on the cutting tool which would otherwise break the tip.

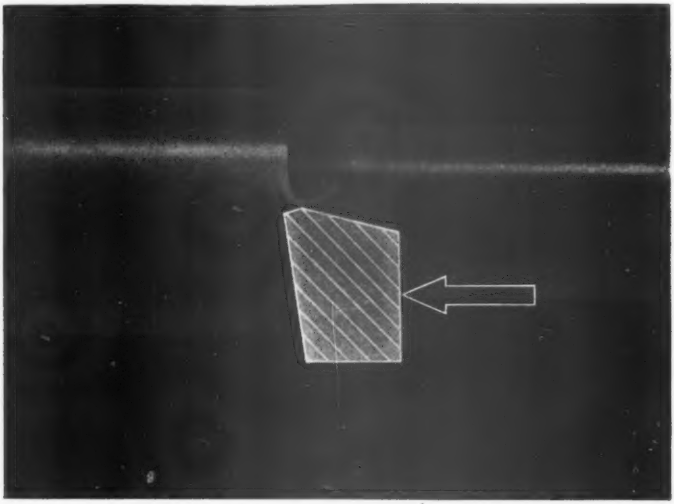


FIG. 12.

In Fig. 12 you will see from the cross-section that there is a primary land on the tool and we actually have two rakes. The primary rake itself is the operative rake, and it obviates the considerable friction of the chip which would otherwise be present by the passage of the chip across the full width of the tool. That, in itself, produces quite a considerable saving in horse-power, and enables higher feeds to be taken than would be possible with a single rake. The principle of primary and secondary rakes is, I think, one to be commended for another reason. It facilitates the adjustment of cutting rake, to meet the variations which occur in workpiece rigidity with components of similar material. The factor of workpiece rigidity has a noticeable influence in the choice of ideal cutting rakes for optimum tool life.

The principle is equally applicable in cases of interrupted cutting on any kind of material, because whilst pressure during the cutting operation itself may be low, the impact load at the moment of entry of the tool can be very high indeed—so high as to twist the tool shank, and it is necessary in jobs of that nature to bear in mind the proportions of the tool shank required at the moment of impact.

Fig. 13 shows a job under interrupted cutting—this was a square billet and it had four slots milled in it. The tool resisted over 30,000 impacts without the slightest deterioration of the cutting edge, merely because there was a negative rake on the tool and the approach angle was 45°, which made sure that the initial impact was taken away from the point of the tool and away from the cutting edge.

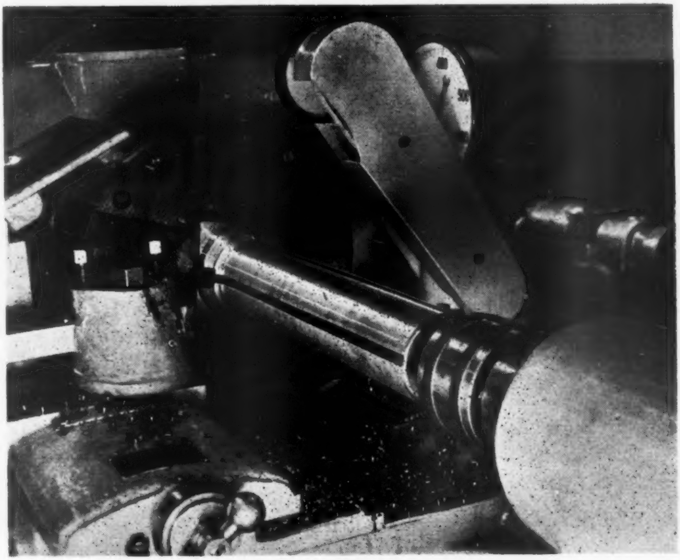


FIG. 13.

Milling cutters should always be designed so that the impact on the cutting edge is taken away from the point of the tool. Turning tools and boring tools should always incorporate the equivalent of a negative helix on a milling cutter.

Fig. 14.

Fig. 14 shows a trepanning tool for producing button blanks. This is something quite new, comprising a solid carbide ring, interchangeable in a steel holder and secured by means of a collar.

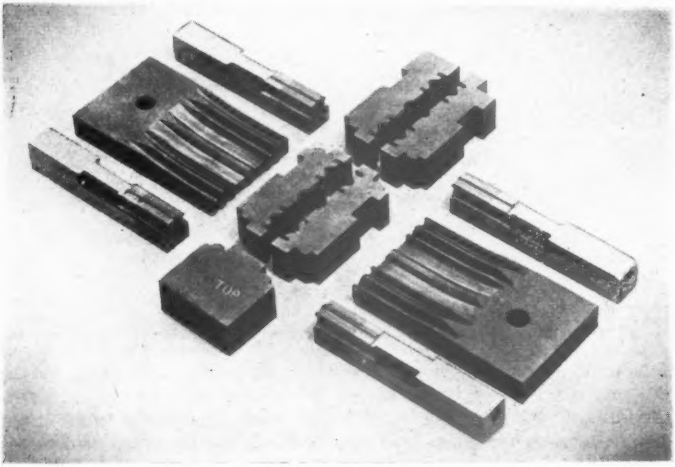


Fig. 15.

Fig. 15 shows a blanking and piercing tool with punches of unbrazed carbide, used in conjunction with carbide segmental dies, which illustrates the practicability of using carbide on heavy impact, direct pressure applications, and whilst a press tool is not a cutting tool, in the accepted sense of the word, it does cut.

Carbide in compression is about 30 times as strong as steel. In shear, it also shows similar advantage as compared with steel. We have successfully applied carbide rings, with interference fits, on steel shafts without the ring breaking and with internal pressures applied up to 15 tons, without any cracking of the carbide due to tensile stresses.

One last point—in reply to Mr. Eatough's mention of coolants. In my opinion, provided that carbides are used exclusively on a machine, coolant is not necessary at all, but if on the same machine, taps, drills or other tools in high speed steel are used, then coolant must be used for them, and the carbide performance will not suffer as a result.

DISCUSSION

Mr. Woodroffe : I beg to differ about milling aluminium alloys with carbide and without a coolant. The aluminium fuses to the carbide and chokes the cutter.

Mr. Eckersley : I think your problem is that you are running at too low a speed. Aluminium alloy has an indentation factor of about .005 in.—by that I mean that before the cutting edge will begin to produce a chip, you must have a penetration of about .005 in. into the material. If the depth of cut or feed per tooth is lower, the carbide will rub and result in adhesion of metallic particles to the tool edge. The secret of cutting aluminium alloys is to cut as fast as the machine will go, at the highest feeds. If you do that, you will not get ' fusion.'

Mr. Woodroffe : We were milling spars at 2,700 s.ft. per minute and without coolant, but the metal ' fused ' to the cutter.

Mr. Eckersley : That is too low a speed to use for optimum results.

Mr. Harrison : We have before us, in the very near future, a very interesting race between the development of tungsten carbide and the machine tool, and it is a question of which will keep pace with which. Mr. Eatough has shown that the machine tool has some leeway to make up. He has pointed out that the operation time is divided into two parts—20 per cent. of which is cutting time and 80 per cent. lost time on other operations.

If tungsten carbide is used, the chip disposal problem will be more difficult to overcome and that gap in time will grow greater

still. It is obvious that chip disposal is a problem which the machine tool people must attack and overcome.

Secondly, as the tungsten carbide side of the race tackles some of the problems, with which so far very great success has not been achieved—and here I refer to screwing, both internal and external (a lesser amount of success is apparent in operations such as reaming)—when complete success is achieved, then the machines will go faster than ever and we shall have a greater problem of chip disposal. This also affects the operator's safety, as in some operations chips are becoming a real danger.

One thing which already appears very evident is that with high powered tools the general trend was to slow down but with tungsten carbide you speed up. On the developments which are taking place, I would like to hear our speakers' opinions and the difficulties to be overcome in the development of such operations as broaching and tapping. These are directions, I think, in which not much progress has been made.

My experience so far with reaming is that it is not generally used and this seems to indicate that there must be some difficulties.

Mr. Eckersley : Considerable strides have been made recently by a restricted number of machine tool makers in external screwing in the form of rapid chasing. So far, there has been little success with the application of carbide to orthodox screwing dies, principally because of the difficulties of chip disposal, but I believe that the evolution of a tool to overcome these difficulties requires very considerable co-operation and liaison between the machine tool maker of such tackle and the tool designer, and I throw into the pool the accusation that generally speaking the machine tool designer rarely considers the medium of cutting until the tool designer has to face up to the problem.

The production of screw threads in itself is one where there is a considerable divergence of opinion, as to which is more economical. Where tolerances are relatively coarse, a die head will often satisfy the requirement of the product except where very fine thread grinding becomes the fashion, but the limitation of many tools arises from the fear or ignorance of the potential user of the methods of reconditioning those tools. That applies to reaming. It applies to screwing tackle and it applies to drills.

Nobody need have any worry about the grinding and reconditioning of carbides if they remember that, since they have a new material to deal with, they must use new methods.

Broaches are very delicate tools and could easily be ruined by grinding on an unsuitable wheel. I believe that the practice of using diamond impregnated wheels will grow, but it is not growing fast enough to keep pace with the application of tungsten carbide. In other words, the limitation of the tungsten carbide is very often

induced by the fear on the part of the user of the necessity to acquire new technique in application and maintenance.

Contrary to Mr. Harrison's experience, reamers are in very wide use. We make a thousand per week and somebody is using them. Regrinding of a carbide reamer is not quite so easy as the re-grinding of a steel reamer because a different technique is required, and that technique is necessary before good performances can be assured. I refer to the danger of cracking the carbide on such small tips. Similarly, in broaching—a broach is an expensive tool, even in high speed steel, and there is a natural reluctance to sink a large amount of money into a tool which only needs to be dropped once to be completely scrapped.

I think, on the whole, that Mr. Harrison's questions—in so far as these points are concerned—are very largely answered by the keenness of the user to acquire unto himself a new technique and to convince himself that because a diamond wheel costs thirty to forty times more than an orthodox wheel, it does not necessarily mean money thrown away. We have in our factory a large battery of grinding machines, for which a lot of money is spent every year on diamond wheels. We have acquired the technique of grinding tools by bitter experience, but our knowledge is available to anyone who wishes to learn it.

Mr. Cotton : Mr. Eatough stresses the question of speed, and I think it should be borne in mind that feed is dependent on speed. I feel that the time has come when a compromise has to be made between the two, leading to fewer grades of tungsten carbide at the choice of the customer. I do not mean to say that the more specialised grades of carbide should be discarded entirely, but could be called for specially.

From the practical user's point of view, the nomenclature regarding grades is all very well for the people constantly buying them. For instance, we know that Ardoloy ' 2.A ' is equivalent to Wimet ' N,' but there are far too many symbols in use to make the job easy to handle. The grinding wheel people have at last got down to the same grading regarding the trade.

Regarding the training of the operators, Mr. Eckersley has just told us that facilities are available whereby we can learn how to handle tungsten carbide, but in my experience, particularly with the older operators, it is most difficult to get them to drop the high speed steel practice. As we all know, the very fine thin edge of the lapping tool will not stand pressures which are applied to it. In my opinion, again, the best method when dealing with carbide is the exchange system, whereby you have a skilled man with knowledge of carbide grinding, the blunt tools being taken to him for re-grinding and replaced by properly sharpened tools.

The large manufacturers can afford special re-grinding equipment, and the necessary labour and facilities, but we must not forget the small factories who want to take advantage of carbide, but cannot afford it.

Mr. EATOUGH: There is just one small point—I have an operator running a rather big experimental lathe. This operator came out of the mines and has never run any other machine. He is one of the best carbide operators we have on the ground.

Mr. ECKERSLEY: When Rolls-Royce and Ford get together and come to the same conclusion about standardising their cars, then we will make the same grades of carbide as everyone else. There is nothing we would like better than to make only one grade of carbide. The manufacturer must have some pride in his product, and we believe that we make better carbide than anyone else.

With regard to the education of the employee—education is always a very slow process. When carbide came into this country in 1928, we knew nothing about it. We have made a great deal of progress and the volume of carbide used today in every industry, except breweries, is colossal, and will grow still more.

On the question of reconditioning carbides, Mr. Cotton is quite right. A large firm will appreciate the economy of a centralised reconditioning department, and a considerable number of machine shops have adopted that principle with success. A small shop can help itself to become efficient by training a skilled man, with a considerable amount of pride in his work, to recondition all the carbide tools, and so allow the unskilled man more operating time, without any reduction in his piece-work earnings. You can train one man, where you cannot train thirty or forty.

We believe that the best way to train both machine operators and tool grinders is to take them away from their normal environment and put them somewhere else. We established a School, some two years ago, which has been very successful in changing the point of view of operators and reconditioners.

A VISITOR: With reference to carbide-tipped broaches—how is the new tip inserted when one breaks in the middle? We have heard a lot about screwings and turning, but what contribution has the carbide industry made to gear cutting? Are there any carbide-tipped hobs or shaping cutters?

Mr. ECKERSLEY: One company has developed a type of broach for use in their own factory, incorporating a system of carbide rings, so that if a ring is broken the whole of the broach can be taken apart and the replacement ring put on.

Another advantage is that as the broach wears, the first ring is taken off and the others are moved up one. This is satisfactory for circular broaches but there are broaches of many shapes—and

broaching will develop as people are acquainted with using broaches on quantity production jobs, or where slots or holes of a particular size are produced in considerable quantity. I made my first broach in carbide in 1927, for producing key-ways, with pieces of carbide clamped in the same way as a honing stick is held. I was able to make, with very considerable economy, a range of broaches for key-ways which lasted for many years, without any breakage at all. I think the limitation of the use of broaches is mostly a matter of fear of the high cost.

With gear cutters, there has been some experimental work carried out on a variety of types of machines. The simplest type of cutter is, I think, the " Sunderland " gear shaper cutter and the difficulty in that case is that the use of the " Sunderland " gear tool grinds the tool so many times that it finishes up, invariably, no more than $\frac{1}{8}$ in. thick. We cannot face up to that sort of thing yet, but there may be possibilities in solid pieces of carbide.

We are experimenting at the moment with Gleason cutters, but they present very considerable problems in regrinding. Special machines and wheels are required for that type of cutter. Hobs are fairly simple, but costly. We have made hobs which are in use now on gears in several parts of the country. We have one outstanding job which has a bearing on the talk which Mr. Eatough gave.

A firm came to us about eighteen months ago with the problem of producing 30 ft. diameter gears, with 5 in. circular pitch. This gear was on the machine for eight weeks at a time, and the man who operated the machine had nothing to do but watch it. The feed of the hob on that job was $\frac{9}{16}$ in. per minute. We made up a cutter which we successfully applied on an experimental basis, at a feed rate of 10 in. per minute. The firm are now designing a machine which will feed at that rate. It means having a machine of an entirely unorthodox build, but the firm in question know that when they have built this machine it will have a 75 h.p. motor instead of a $7\frac{1}{2}$ h.p. motor, which they have at present, and the gear will be on the machine for five days, instead of eight weeks. There you have a classic example where cutting time is also the idle time.

Mr. Eatough : I would like to mention one or two points with regard to reciprocating cutters and Fellows gear cutters, etc. One of the main troubles with such cutters is to get a reasonable cutting speed suitable for carbide. One cutter I saw in use had put up a remarkable show, even though there had been considerable vibration.

Regarding shaving tools, I have not seen any carbide shaving tools and I do not think we are going to. The tools themselves

are very delicate ; the edges have to be very sharp and the blades are subject to a certain amount of tension, and I cannot see that they will stand up in carbide.

Mr. Fields : I rather think that Mr. Eckersley was talking with his tongue in his cheek with regard to coolants. I am employed by a very large motor car company, using many machine tools, and we have to use machines designed about 15 years ago. We have found that using coolants with tungsten carbide is a very big improvement, and has improved our cutting life by 300 per cent. On flywheels, which are 50 per cent. iron and 50 per cent. steel composition, there is a lot of dust cutting with the carbide dry, but using coolant, our troubles are over.

Mr. Eckersley : This is the exception which proves the rule. Coolant does act in improving the cutting performance of the tool by shifting the 'muck' which would otherwise restrict that performance. The same object can be achieved by using compressed air.

In the first place, what is the object in using coolant on any high speed steel tool ? It is to preserve the hardness of the tool by reducing the temperature at the cutting edge, which would otherwise be induced by the tool on the workpiece. When a cutting tool is in use, whatever its type—H.S.S., Stellite, Carbide, Carbon Steel—or any other material which may cut metal—the wear on the tool invariably takes place first just below the cutting edge. That is induced by the rubbing of the tool during intermittent deflection on the part of the job which has already been cut, and it is also aggravated by the fact that when the tool parts the chip immediately above the cutting edge, there is a wedge-shaped space, and the higher that space is, the more dust is produced by the partition of the chip from the parent metal itself ; this dust falls down and is dragged by the workpiece past the front clearance. When we have dust from a casting, that in itself can wear the tool below the cutting edge, but if it is necessary or desirable to shift all that 'muck,' then coolant will do it.

In conditions like that, I would rather not use the word 'coolant' at all. 'Liquid' or 'swiller' would be more appropriate.

Another case is in deep hole drilling. It is impossible to get the swarf out unless either water or air is pumped through the drill to swill the swarf out of the way, otherwise it will jam.

Mr. Rutter : To refer back to the broaching question, I think the main reason why tungsten carbide has not been developed in broaching is that on the modern broaching machine you cannot get the speed and, as already stated, I think the price would be more or less prohibitive.

Mr. Eckersley : I would remind you that about 1932 the Cincinnati Milling Machine Company, of the U.S.A., made some

broaching machines for General Motors Corporation, for broaching cylinder blocks in one pass. The floor to floor time was phenomenal. The broaching speed was little higher than for normal jobs of that nature—that is, they were, I think, broaching at speeds in the region of 20 in. per minute. The cost of a broach 10 in. wide was about 25,000 dollars (£5,000), and the machine itself cost about £3,500. They are at this moment making carbide broaches in the States, but I do not know how they manage to justify the cost. Broaches are delicate jobs and not easy to replace. The teeth on the Cincinnati job, designed to produce a flat surface, are merely slabs of carbide, built on to steel-backed pieces in a very heavy frame and with guide plates to avoid deflection.

Mr. RUTTER: I am speaking generally now—I think you refer to a special application. Take a 12-spline hole, with a broach 48 in. long, and probably one set of two or three broaches. The price in high speed steel is in the region of £150, so what would it be in tungsten carbide? There is always the danger of negligence. Even with high speed steel, damage is easily done.

Mr. ECKERSLEY: The solution may be to make an entirely new type of broaching machine with a considerably greater length of stroke and different form of holding the broach. I can visualise something in the nature of a heavy planing machine for surface broaching.

Mr. BROWN: Mr. Eckersley advised a way of putting a negative rake on a positive rake tool, to take care of the cutting edge, and said that the horse-power reduction was considerable and that the chip was flowing through the air. Would he please explain to me how it is possible to break up the chip and so reduce the problem of chip disposal?

Mr. ECKERSLEY: That particular sketch (Fig. 12) applies only to short cuts, but it is possible so to dispose the cutting edge, in relation to the work, that a curled chip is naturally formed. In the case of certain long turning jobs, or big diameter work, locomotive wheels for example, the chip is curled over. Bearing in mind that material such as locomotive wheels are made from is very difficult to break anyway—and must be curled—the tool is designed with a cutting edge which has a forward drop of about 30° to 45°, with a positive rake which is just as acute, and with a true cutting rake of somewhere about 10°. The chip will curl over naturally because of the difference in speed of the chip across its width. In this case, a chip curl of about 3 in. diameter is obtained.

Where this is not possible, or where very long turnings are obtained, it is not practicable to use this principle exactly in that form, but the principle can still be used to some extent by the production of a groove on the tool, narrower at the back than at the front.

Mr. Brown: The use of a chip groove loses the advantage you have described with primary and secondary rakes.

Mr. Eckersley: The principle of primary and secondary rakes is more applicable to interrupted cuts, milling, and short cuts generally.

Mr. Smith: May I ask Mr. Eckersley whether he has any experience in form milling Nimonic 80 with carbide milling cutters?

Mr. Eckersley: This is a very difficult material to cut by methods other than grinding. Nimonics were designed for one particular purpose and, unfortunately, the shapes of these components do not lend themselves always to grinding methods. Since machinability presents a very difficult problem, we have produced an alternative material which does not need machining at all. It is now growing in use on jobs such as these, for which Nimonics were designed.

This alternative is one of the variants of aluminium oxide. Accuracy of form is somewhere in the region of .002 in. tolerance. Where this tolerance is not fine enough, there are ways and means of grinding, by using diamond impregnated wheels, which are reasonably satisfactory from the point of view of economy.

Mr. Reynoldson: I have always understood that one of the most important factors of negative rake is that it puts the carbide 100 per cent. under compression. Is this true?

Mr. Eckersley: Yes, the direction of pressure is changed, and avoids the risk of overloading the cutting edge.

Mr. Gill: Can Mr. Eckersley explain why, in cutting Nimonics, high speed steels are found to be better?

Mr. Eckersley: It is merely a matter of incidence of pressure and Nimonics produce a cutting pressure exceedingly higher than that of any other known material, and so far we have been unable to apply the same principle that we normally apply. I mentioned that in the case of high pressure, it is desirable to lengthen the cutting edge. In cutting Nimonic, the component itself determines the length of the cutting edge which can be used. Alternatively, we might be tempted to use negative rakes. Nimonics cannot be cut with negative rakes, because of work-hardening. It is necessary to use a high cutting rake to get into that material and, so far, high speed steel is the only material which will withstand the pressure with the necessary rakes.

Nobody can say that high speed steel will offer an economical solution to the machining of Nimonics. I know people who have this problem who have actually changed the design of the component to enable them to grind. Nimonics are applied almost exclusively to turbine blades and in that respect, there are two factors which are almost insurmountable from the tooling engineer's point of view. The machinability of the material is controlled almost entirely by the extremely high tendency for work-hardening. The

use of a grinding wheel of any form embodies the application of a very large number of cutting points, which scrape the surface of the work, with consequent reduction in pressure at that particular point.

I have said that the limitations on the cutting tool imposed by factors of design, coupled with the peculiarities of the material itself, make it an exceedingly difficult job for the production engineer. Rolls-Royce Ltd., use some little cups which are drawn out of Nimonic sheet, and the drawing operation puts the material in tension. We have no difficulty in drawing those shells with carbide tools. Now steel tools, curiously enough, are affected adversely by the drawing operation. The abrasion of the Nimonic material is so high that steel tools fail after two components. Carbide tools are used because of their resistance to abrasion. There you have a material which behaves very differently when stresses are reversed.

A VISITOR : I am rather interested in press tool applications. From my experience, it is usual that a steel punch will only pierce up to the same thickness of material as its diameter, and Mr. Eckersley's sketch shows a very small punch which appears to be considerably less than the thickness of material, not specified. It seems that we may have some material here with which we can punch really small holes, in thick material. There are two things to be done in punching—the first is to punch and the second to take the punch out afterwards. I have usually found that the punch breaks on the stripping operation and I should like to know whether Mr. Eckersley has carried this any further, and also the thickness of the material.

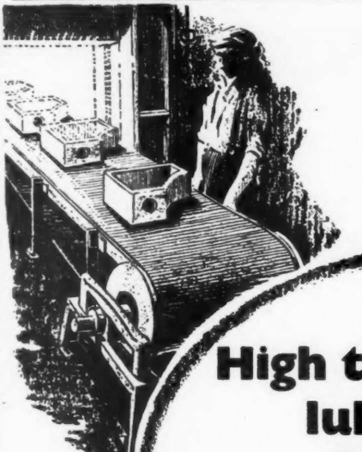
Mr. ECKERSLEY : The same rules apply in blanking for steel tools as in carbide. The thickness which can be pierced by any punch is determined by the ability to withdraw the punch after the hole is pierced. Obviously, on very tiny punches, a clearance has still to be there, in order to produce a cutting edge, to avoid the punch jamming in the hole. But it is not necessary, when piercing a hole, that the punch should penetrate right through the plate. There is a point in the thickness of all material where shearing is complete, and at that point the punch should not penetrate any further. In other words, the punch merely starts the shearing and the blank finishes the job.

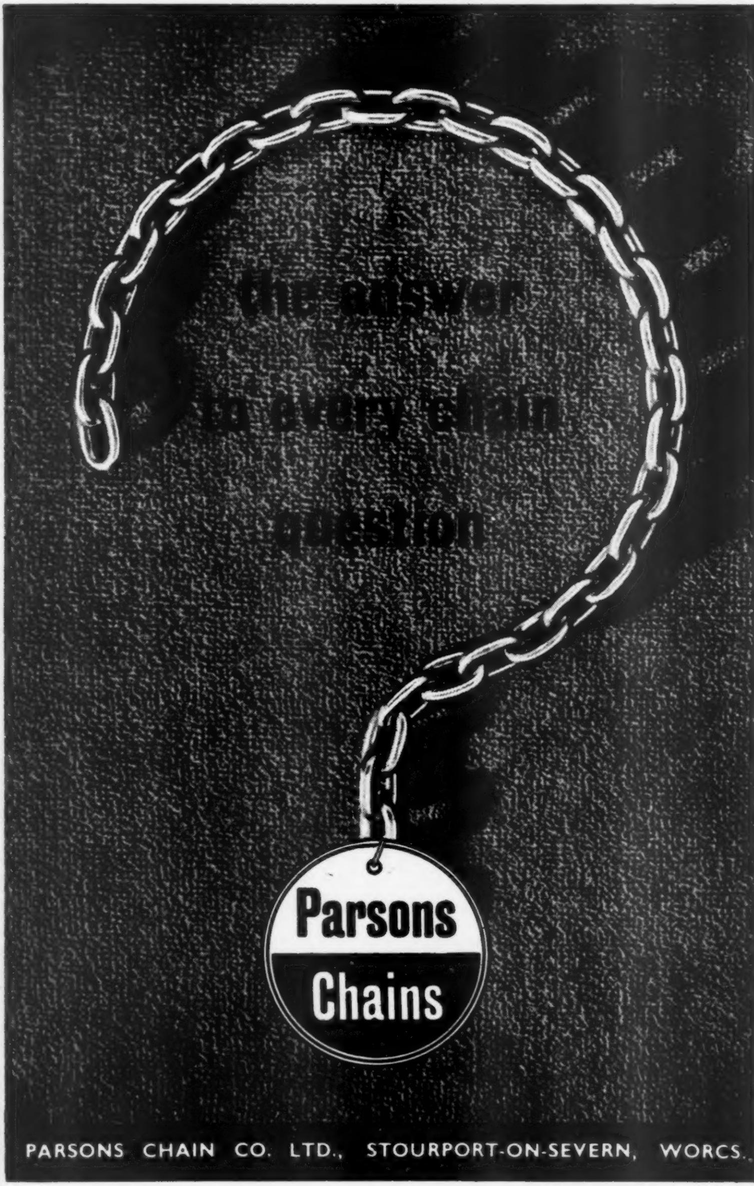
If you look round the edge of pressings you will find that there is a shear line on the material, and that is the depth to which the punch should penetrate in shearing that material. The main advantage of tungsten carbide in press tools lies again in its resistance to abrasion. Carbide has a considerable advantage over steel, in its resistance to abrasion, because not only have we got consistent hardness in tungsten carbide, but we also have a high resistance to compression.

The impact load which is applied in piercing is very considerable, but fortunately it is carried over a very big perimeter, so that the unit pressure along the cutting edge is light.

The life factor is generally in the region of 15/1, and it is particularly useful in those materials which are highly abrasive. There is another factor which assists the economy of carbide ; the wear on a steel tool, rather peculiarly, is very much more than that on a carbide tool. By that I mean that at the appropriate number of blanks when the steel tool requires regrinding, it is usually necessary to take .005 in. or .006 in. off the face of the tool. For fifteen times the number of blanks a carbide die will only require removal of .001 in. to .002 in., which improves the life of the carbide enormously.

The reason for that is that carbide does not score, but steel will produce a dust during the shearing operation and that scores the walls of the die and the sides of the punch, and causes deep grooves which require a much deeper face removal when reconditioning.

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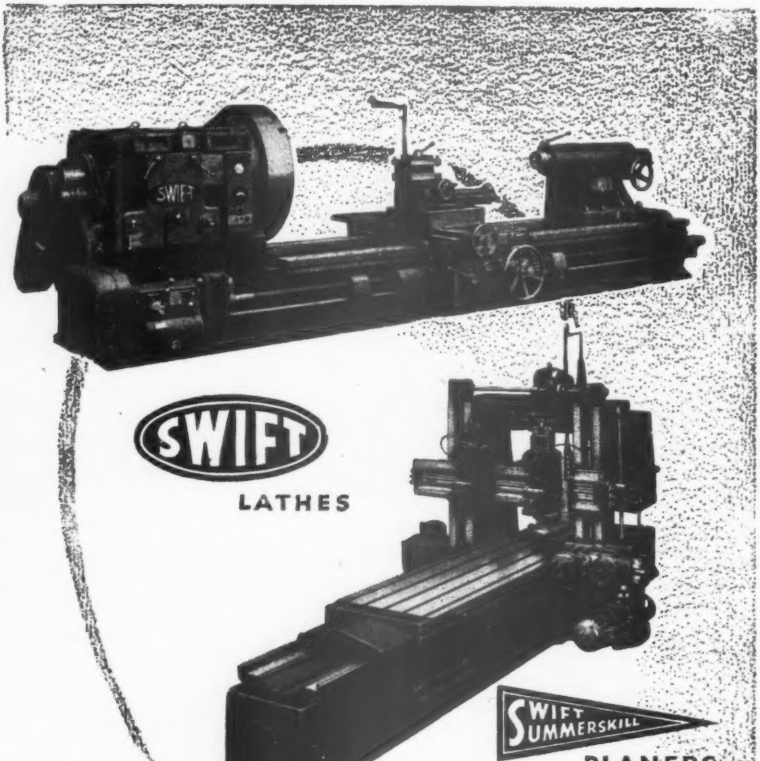
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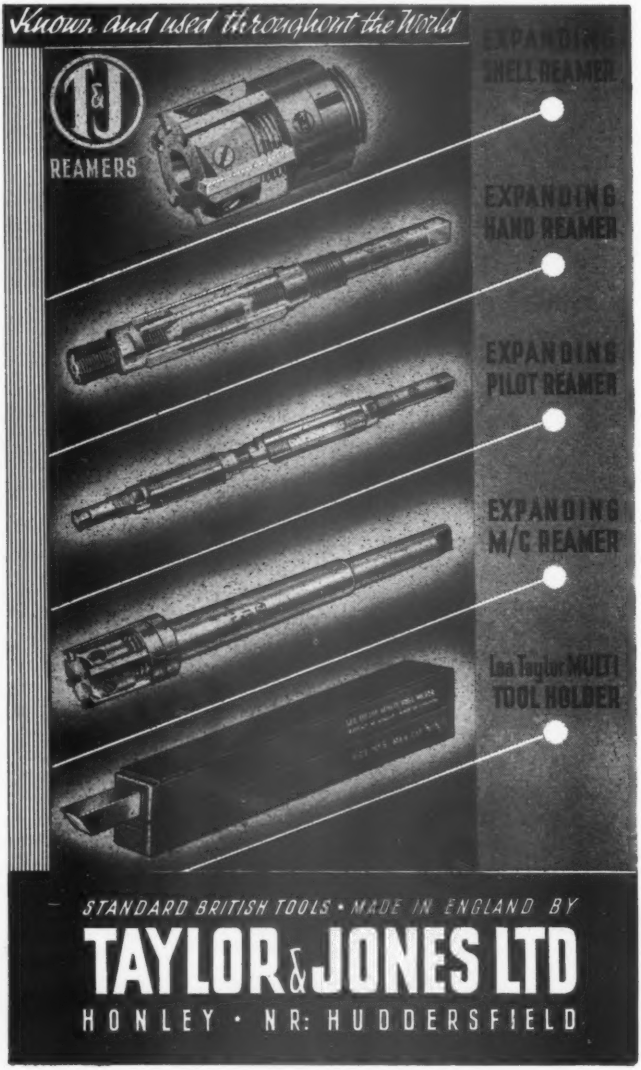
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INDEX TO ADVERTISEMENTS

	Page
Abwood Tool & Engineering Co. Ltd.	—
Acheson Colloids, Ltd.	xxiii
Adam Machine Tool Co., Ltd.	Lviii
Ajax Machine Tool Co. Ltd.	xxvi
Arnott & Harrison, Ltd.	—
Automatic Coil Winder and Electrical Equipment Co. Ltd.	xLiv
Barber & Colman, Ltd.	Lvii
Benton & Stone, Ltd.	xLi
Birkett, T. M., & Sons, Ltd.	Lvi
Birlec, Ltd.	—
Birmingham Aluminium Casting (1903) Co. Ltd.	iii
Bratby & Hinchliffe, Ltd.	Lv
British Steel Founders' Association	xxxii
British Tyre & Rubber Co., Ltd.	xLviii
Brooke Tool Manufacturing Co. Ltd., The	—
Broom & Wade Ltd.	—
Bull Motors, Ltd.	xi
Burton, Griffiths & Co. Ltd.	xxxix
Camerer Cuss & Co.	—
Catmur Machine Tool Corporation, Ltd.	xxxiv
Churchill, Charles & Co., Ltd.	xxix
Cincinatti Milling Machines, Ltd.	xL
Climax Rock Drill and Engineering Works, Ltd.	Lxi
Coventry Gauge & Tool Co., Ltd.	xviii
Craven Bros. (Manchester) Ltd.	Lix
Crompton Parkinson, Ltd.	xxxiii
Dawson Bros., Ltd.	xx
Dean, Smith & Grace, Ltd.	xxxv
De Havilland Aircraft Co. Ltd., The	xvii
Donovan Electrical Co., Ltd.	—
Drummond Bros., Ltd.	xix
E.M.B. Co., Ltd.	x
English Electric Co. Ltd., The	—
Exors. of James Mills, Ltd.	xiv
Fescol, Ltd.	ix
Firth, Thos., & John Brown Ltd.	—
Flame Hardeners Ltd.	Lvi
Fletcher Miller Ltd.	xLvi
Gill, Samuel & Sons (Engineers) Ltd.	—
Gledhill-Brook Time Recorders Ltd.	—
G.P.A. Tools & Gauges, Ltd.	xxviii
Guylee, Frank, & Son, Ltd.	*Inside Back Cover*
Harris, John, Tools Ltd.	xxiv
Harrison, T. S., & Sons, Ltd.	viii
Hendry, James, Ltd.	—
Herbert, Alfred, Ltd.	xLii, xLiii
Hilger & Watts, Ltd.	—
Holman Bros. Ltd.	*Back Cover*
Hoover, Ltd.	xxvii
Hordern, Mason & Edwards, Ltd.	Lxv
Hughes, F. A., & Co., Ltd.	xiii
Humphris & Sons Ltd.	—
Imperial Smelting Corporation, Ltd.	xxxvi
Johansson, C. E., Ltd.	Lx
Keelavite Rotary Pumps & Motors, Ltd.	xxx
King, Geo. W., Ltd.	—
Lang, John, & Sons, Ltd.	v
Linread, Ltd.	xLv
Lloyd, Richard, Ltd.	—
Lund, John, Ltd.	L
Mercer, Thos., Ltd.	—
Ministry of Fuel and Power	—
Mollart Engineering Co., Ltd.	—
Moore & Wright (Sheffield) Ltd.	Liv
Morgan, George, Ltd.	—
Motor Gear & Engineering Co., Ltd.	Lxiv
McKechnie Bros. Ltd.	Liii
Mycalex Co. Ltd., The	—
Newall, A. P., & Co., Ltd.	vii
Newall Group Sales Ltd.	—
Norton Grinding Wheel Co., Ltd.	—
Osborn, Samuel & Co., Ltd.	xLvii
Parkinson, J., & Son (Shipley) Ltd.	—
Parsons Chain Co. Ltd.	xxv
Petroleum Engineering & Trading Co. Ltd.	Lxiv
Pitman, Sir Isaac, & Sons, Ltd.	—
Pitter Gauge & Precision Tool Co. Ltd.	—
Protolite, Ltd.	xxxvii
Pryor, Edward, & Son, Ltd.	—
Pultra, Ltd.	xv
Punfield & Barstow (Mouldings) Ltd.	Lxiii
Pyrene Co. Ltd., The	—
Quasi-Arc Co. Ltd., The	xv
Reavell & Co., Ltd.	xLix
Remington Rand Ltd.	—
Rockwell Machine Tool Co. Ltd.	—
Sanderson Bros. & Newbould, Ltd.	Liv
Sheffield Twist Drill & Steel Co., Ltd., The	—
Smallpiece Ltd.	—
Sterling Metals Ltd.	—
Sunbeam Anti-Corrosives, Ltd.	Lx
Swift, Geo., & Son, Ltd.	xxxviii
Talbot-Stead Tube Co. Ltd.	—
Taylor & Jones, Ltd.	Lii
Technically Controlled Castings Group, The	Lxii
Tecnaphot, Ltd.	Lviii
Timbrell & Wright, Ltd.	—
Towler Bros. (Patents) Ltd.	—
Triefus & Co. Ltd.	*Inside Front Cover*
Tyne Truck & Trolley Co. Ltd.	—
Unbrako Socket Screw Co., Ltd.	xii
Universal Tools, Ltd.	Lxii
Van Moppes & Sons (Diamond Tools) Ltd.	xvi
Vaughan, Edgar, & Co. Ltd.	—
Ward, H. W., & Co., Ltd.	iv
Ward, Thos., W., Ltd.	xxxi
Wickman, A. C., Ltd.	vi, Li
Williams & James (Engineers) Ltd.	—
Wild Barfield Electric Furnaces Ltd.	xxi
Wolverhampton Die Casting Co., Ltd.	xxii
Zinc Alloy Die Casters Association	—

Page
v
XLV
—
L
—
—
—
Liv
—
Lxiv
Liii
—
vii
—
—
XLvii
—
xxv
Lxiv
—
—
xxxvii
—
xv
Lxiii
—
xv
XLix
—
—
Liv
—
—
—
LX
xxxviii
—
Lii
LXii
Lviii
—
—
t Cover
—
xii
LXii
xvi
—
iv
xxxi
vi, Li
—
xxi
xxii
—

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